26.3
Part 2

Design and Technology Education: An International Journal

Design and Technology: An International Journal

Volume 26
Number 3
Part 2
ISSN 2040-8633 (online)
November 2021

Design and Technology Education: An International Journal
(formerly The Journal of Design and Technology Education) is published three times a year

Contributions
All contributions and materials for review should be made through the Journal website at:
https://ojs.lboro.ac.uk/DATE/index

D&T Association membership
To join the D&T association, or request further details on membership please contact:
Jacqui Eborall, Membership Secretary
Tel: 01789 470007
email: membership@data.org.uk

Issue 26.3 Part 2

Table of Contents 173-174

Guest Editorial
Continuity and adaptability in design and engineering education for a knowledge age

Ross Brisco, University of Strathclyde, UK
Anne Louise Bang, VIA University College, Denmark

In 2020, the world as we knew it changed, and the organisers and participants of the International Conference on Engineering & Product Design Education (E&PDE) had to adapt to this change through a transition to an online conference. 2020 and 2021 will always be unique years for the conference, not only because they were online, but they were the first to be hosted sequentially by the same university host and the same local conference team. We must thank the team at VIA Design + Business, VIA University College in Denmark for their outstanding efforts and success in delivering the conference.

The 22nd and 23rd international E&PDE conferences brought together 126 delegates from over 23 countries for the first time since the COVID pandemic began. 168 papers were published on the themes of *The Value of Design & Engineering Education in a Knowledge Age* and *Continuity and Adaptability in Design and Engineering Education*. The E&PDE conference series has been jointly organised and held annually since 1999 by the Design Society Special Interest Group on Design Education and the Institution of Engineering Designers. We celebrate over 20 years of this collaboration and all who have contributed to the conference over the years. Also, we thank those authors who made the journey with us to prepare extended manuscripts for the DATE journal and the reviewers from the E&PDE community who supported the review process. We hope to continue the special relationship between DATE and E&PDE for many years to come.

This special edition aims to explore how educators will tackle changing engineering and design practices in the coming years in line with the demands of students and industry. This sentiment comes from a need to share knowledge and experiences in engineering and design education and discuss how barriers might be overcome.

In the Knowledge Age, technology and ideas are the main sources of economic growth, and this requires workers with new and different skills. Knowledge is more than what is in the minds of experts or classified within separate disciplines. Knowledge is now defined and valued not only by what it is but also by its potential as a driver for innovation. Within technology education, we should be aware of the future requirements, and support skills development in our students. These changes have major implications for our educational system. We need to empower students to be able to locate, evaluate and work creatively with the knowledge to generate new and improved solutions that can be implemented in practice.

These days, we are witnessing a severe environmental crisis that calls for a greener approach for all industries. Digital and technological development offers new alternative ways to work. We experience global challenges of public societies and healthcare systems that demand close attention to risk and uncertainty. These environmental, technological and societal changes and challenges have major implications on our educational system within design and engineering. They impact what we teach, the way we teach and why we teach. We need to educate designers and engineers so that, in addition to being proficiently skilled, they can work in cross-disciplinary teams and can contribute to a dynamic and constantly evolving processes and systems in a fragile and unpredictable world.

The special edition was designed to give specific and actionable examples for the Design and Technology Education community. The guest editors Ross and Anne Louise have considered papers from the entire design education experience to give a flavour of the state of the art within the E&PDE community. We aimed to cover the entire design process of Discover, Define, Develop and Deliver, and those aspects important to educators such as course design and feedback. In particular, we have noticed a huge focus on skills and tools discussed at E&PDE, and we have many examples within the special edition. We hope you will enjoy the perspective that we have prepared.

The first paper is *Alone in the sustainable wilderness; transforming sustainable competences and didactics in a design for change education*. In this paper Thomas Østergaard discusses the growing problem with the limited number of interventions when it comes to Education for Sustainable Development. Through evaluation, Thomas discusses the impact that a reflective Decoding Creativity Tool (DCT) tool can have on Education for Sustainable Transformation and the dichotomy between the wishes of UNESCO for better educational environments and the reality of education today.

In *Integrated studio approach to motivate collaboration in design projects,* Virginie Tessier shares a model for learning teamwork skills with the motivation to fill gaps associated with the pedagogical integration of teamwork in design curricula. The proposed model allows for a systemic understanding of teamwork skills that should be acquired during design training. The model encourages a deeper understanding of skills building for more effective and complex design teams.

In *Refining a pedagogical approach for employing design thinking as a catalyst*, Raghavendra Gudur, Deana McDonagh, Maurita T. Harris and Wendy A. Rogers reflect on the impact of the success of STEM and the lessons that design thinking has played as a spark for educational change. From an investigation of a health innovation project, the authors can determine the skill set needed for designers, health and technology professionals to make a significant contribution to its overall outcome.

In *Soft skills in design education, identification, classification, and relations: Proposal of a conceptual map*, Ana Paula Nazaré de Freitas and Rita Assoreira Almedra present an analysis of a worldwide investigation into the importance of soft skills in design. A hierarchy of skills was created identifying those that are gateways skills that act as enablers for high order skills. Practical approaches are discussed to realise the outcomes.

In *Which visualisation tools and why? Evaluating perceptions of student and practicing designers toward Digital Sketching*, Charlie Ranscombe, Wenwen Zhang, Boris Eisenbart and Blair Kuys discuss how digital sketching tools can be characterised within the early stages of the design process. The authors reflect on the contradiction between the creation of visualisations to gain expert insight and those used to advance the design process.

In *How can comparative judgement become an effective means toward providing clear formative feedback to students to improve their learning process during their product-service-system design project?* Ivo Dewit, Sarah Rohaert and David Corradi reflect on the effectiveness of feedback in higher education. Comparative Judgement is employed as a lens to analyse feedback and as a tool for more effective feedback.

In *A blended approach to design education through clinical immersions and industry partnerships in design for healthcare*, Louise Kiernan, Eoin White and Kellie Morrissey present a hybrid approach in health design education following a bottom-up approach to facilitate design research in a clinical setting. Examples of how this was achieved in a blended model are presented which are relevant now more than ever due to the COVID-19 pandemic.

In *Exploring How Degree Apprentices Experience Their Engineering Identity Through Life Story Interviews and the Twenty Statement Test (TST),* Elena Liquete, Elies Dekoninck and Gina Wisker discuss the process of building an understanding of engineering identity formation in undergraduates studying for an engineering apprenticeship degree. The purpose of the article is to propose actionable changes to engineering education that may better support the development of an engineering identity and therefore encourage graduates towards an engineering profession.

In *Social Connectedness and Online Design Learning Experience in the Indian Context*, Christy Vivek Gogu and Jyoti Kumar report on perceptions of students' social connectedness in virtual classrooms. Students from five design schools were surveyed for a comparative understanding, and although there were many technological issues, the factors that influenced perceived connectedness were those that may impact the same on campus. Then, there are opportunities for pedagogical knowledge transfer between domains.

In *The connectivist design studio*, Miroslava Nadkova Petrova makes the argument that the contents of a higher education class should not be simply adapted to an online version in the transition to online learning, but an entirely new learning experience should be created. The principles of connectivism are used to recognise the impact of technology on the learning processes in the redesign of two online design studio classes and the classes are evaluated.

In this guest issue we also include a reflection article. In *Mechanical engineering design, learning from the past to design a better future?* Martin Edward Sole, Patrick Barber and Ian Turner present a reflection on the change in design education from the perspective of the skills required in aircraft manufacture through the ages and the change in skills into the computer age. Whilst not resisting the change the authors document their argument that we should not lose sight of the educational practices of the past and the benefits for the time compared with modern engineers.

Reflection

Mechanical engineering design, learning from the past to design a better future?

Martin Edward Sole, University of Derby, UK
Patrick Barber, University of Derby, UK
Ian Turner, University of Derby, UK

Abstract

The economic importance of design, and design engineers to the success of a company has led to the exponential growth in the demand for qualified design engineers. To fill this demand, colleges and universities provide the best training available so that, after graduation these engineers will provide significant input from the first day of work. We live in a time known as industry 4.0 or the 4th Industrial Revolution, where computer power rules and takes on greater tasks, freeing up time for the design engineer to design more and more complex designs.

Sometimes, it is good to stop, and take a breath to review our practices and remind ourselves of things we may have forgotten. It is true that we can design complex mechanisms and systems, in times past many of these would not be possible. But can we learn or be reminded of good practice by taking a journey through some of the design methods from the past. This paper will travel back to the 2nd century BC and look at cutting edge water pump design and the importance of a good literature review. It will highlight a serious gap in knowledge when comparing full-time and part-time students in our modern age. Airship design will be reviewed, the R100, R38 and R101 to remind us of the need to cross check design calculations. Looking at the beauty of Concorde design will remind us of the requirement in any design of good planning and regular meetings. This journey will finish by looking at the design process of the Boeing 777 commercial airliner, one of the first designs to use Computer Aided Design (CAD) and Computer Aided Manufacture (CAM). The use of Design Build Teams (DBT) with cross-disciplinary experts who can reside anywhere in the world will be considered. The reviewed historical examples may at first glance appear happen-stance but are in fact linked, and demonstrate a continuing growth in the ability, knowledge, complexity, and techniques of engineering design.

This step back in time will remind teachers of some basic principles when teaching design to future design engineers. Designs have become more complex in this modern age, but it would be incorrect to say that complex design did not exist in times past. Before the internet, aircraft were built, global communication systems existed, men went to the moon.

Keywords

Design, Teams, Past, Teaching, Industry 4.0, 3D Modelling

Introduction

The importance of design cannot be over-estimated. It is a true and obvious statement that everything we use to-day, everything we have used in the past, and everything we are going to use in the future, a design engineer, or design team created it.

Effective use of design can bring financial benefits to a company. The British government was the first in the world to recognise the importance of design when it set up the Council of Industrial Design, which later became known as the Design Council. The United Kingdom (UK) has the largest design sector in Europe and the second largest in the world. The Design Council (2018), who are an independent charity and government advisor on design make clear the importance of design and designers. Design contributed £71.7 billion to the UK economy during 2018. For every £100 a business spent on design, their turnover increased by £225 (Design Council, 2018). The design economy is adding jobs at more than three times the national average. During 2014, 1.6 million people were employed across the design economy, that is 5% of the workforce in the UK (Design Council, 2018).

For over 50 years, Moor's law has been found true. The number of transistors that can be manufactured on an integrated circuit doubles approximately every 18 months (Swan, 2020). The effect, in computing terms is to produce ever more powerful computers, a new generation of faster computer hardware. These more powerful computers have made possible the development of more sophisticated software. In the early 1980's, to design a complex system required many thousands of two-dimensional drawings on paper, depicting three-dimensional parts. Expensive physical mockups or prototypes were required to check for interferences between parts as these were difficult to impossible to identify using two-dimensional drawings. By the 1990's, as computing power increased it was possible, for the first time, to design a complex system, the Boeing 777 commercial aircraft, not on two-dimensional (2D) paper but using three-dimensional (3D) software (Sabbagh, 1996). The traditional design office was replaced with the design world. Geography no longer limited the designer's world. With the internet, complex designs could be produced using design teams who are not required to be in the same physical space. Physical mockups or prototypes were reduced and often no longer necessary, this could all be accomplished with the aid of the new, more powerful computers (Friend, 2018) (Hombergen & Ploeg, 2018).

Whilst collectively, as a society we can celebrate our advances, it is useful to reflect on a time when such complex designs were possible, without the aid of computers. The design of the commercial airliner Concorde is still considered a marvel of technology but was designed without the aid of any computers. If we go back thousands of years in history, we will see complex designs for that age. Let us look at the design methods used and how these methods changed as complexity of design increased. We will see these 'ancient' methods are as applicable today as they were when first applied.

Reviewing the past to develop and improve methods in the present is not new. Examining case study methodology is a tried and tested process that has helped designers and educators apply lessons from the past to today. Auburn University provides eighteen case studies of real-world examples. Pramod et al (2010) argues these case studies can be used to improve mechanical engineering education. Ceccarelli (2021) discusses looking at machines from the past, and their inventors, to determine the trends for the future. These historical examples can be used to motivate future engineers. According to Kotnour (2015), engineering managers can use the past and present to determine the emerging trends, challenges, knowledge roles, and stakeholders needs of the profession. This paper will continue to apply the basic principle of learning from the past to apply to the present and future.

As the complexity of designs increases, the tools we use to design are also increasing in complexity making the teaching of design more difficult. While these modern tools are important and must be taught, it is important not to forget the tried and tested methods of the past. These are the cornerstones of our modern tools.

Research and Knowledge

Go back to the second century BC to meet Philo of Byzantium. Figure 1 is a reproduction of the earliest drawing of his force pump. The design process revolved around functionality. There is little evidence of refinement or aesthetic considerations, but all the essential principles are presented, and the design is unexpectedly complex (Hurst, 1999). It is unlikely that Philo developed any new materials, as the required technology wasn't available to him. It is more likely that he used whatever came to hand, the things he was already familiar with. The method most likely used to design and build the pump was 'trial and error'. Today we would apply the term 'Iterative Design' where the pump would be built, then modified until the function was acceptable. Each successive modification being less involved than the previous one (Hawkes & Abinett, 1984). Today's designer does not have to rely so much on 'trial and error. Our vastly improved knowledge of mechanical principles and the powerful computers and software available to designers makes 'trial and error' nearly a thing of the past. Nearly, because sometimes, the mechanical principles may need to be developed, and computer software can only work on known problems.

Water flows into the partial vacuum created by the upward motion of the piston, and on the down stroke, with the valves reversed, the water is forced up the pipe into the tank. This was a significant advance, or step change from anything that had gone before. This is considered a dynamic product as there is room for significant product development. This, it can be argued, was an invention.

With most inventions, Philo's force pump was refined and next appears in the form of Hero's force pump (Figure 2.) from the first century AD, some 300 years later. The refinements which are most notable are the replacement of two pipes for conveying water to the tank into one pipe, the single actuation beam pivoting in the center and the introduction of a nozzle. This dynamic product can now be considered static, with very little scope for significant product development. The design process was one of incremental improvement in the functionality and efficiency. Hero could determine, possibly with calculations, that for the same amount of effort, or in the same amount of time, he could pump larger quantities of water when compared with Philo's earlier pump. Hero's force pump is an innovation based on Philo's invention (Hurst, 1999).

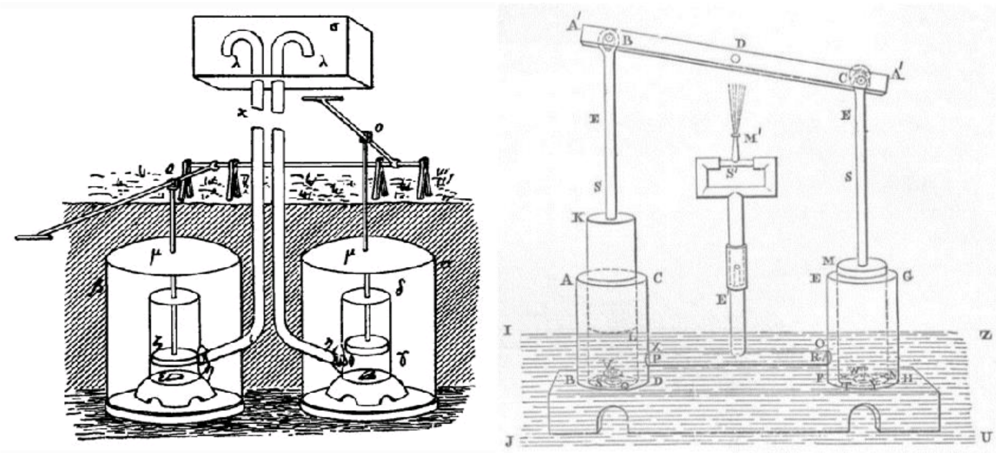


Figure 1. Philo's force pump and Hero's force pump

Moving forward, to the 18th century when Newcomen developed the 'Atmospheric' Steam Engine (White, 2014). Pumps that came before were based on Philo's and Hero's design and were limited by the physical strength of the operator. They could only pump water from a maximum depth of around 12 m (40 ft) as the pumps were drawing water upwards against the force of gravity. The main use of pumps, from Philo's time to the industrial revolution was to pump water out of mines or to provide drinking water. With the power of Newcomen's steam engine, water could be pumped from much greater depths even though its efficiency was only around 8 -10%. This was a dynamic product with room for significant improvement. This improvement came from James Watt's 1769 patented condenser which improved the efficiency of the steam engine to 12 -14% which may not appear to be much but was a major step forward in technology (Selgin & Turner, 2020). The design process of Newcomen and Watt was similar to Philo's and Hero's. The design process was mainly to refine the functionality, to increase the efficiency. The design complexity increase was made possible by new methods of manufacture and materials. With growing knowledge of science, calculations of forces acting on a component could be determined. The Victorians also considered the aesthetics, functionality was important but had to be pleasing the eye.

Early designers probably passed on information by word of mouth. Later they saw the advantages of producing accurate, detailed sketches. Sketches are an important aid in idea generation and a way of piecing together unconnected ideas into design concepts. In our modern era, instead of sketches we use scaled 2D drawings and 3D solid modeling (Dieter & Schmidt, 2009). Most students are adept at using computer graphics and usually have little difficulty in using 2D and 3D Computer Aided Design (CAD) packages, but they struggle to produce useful hand sketches (Stroud & Hildegarde, 2011) and often do not see any need to hand sketch. Sketches should not be considered as less important than 2D drawing and 3D solid modelling produced using computers. The path between sketching of an initial idea and developing it into a finished design is an area that should be given priority in our teaching.

The importance of a thorough literature review is demonstrated here. Hero carried out a literature review and discovered Philo's earlier design. The equivalent of a literature review in Hero's Day involved travelling to the few sources of information available to him. The ancient library at Alexandria with its estimated 400,000 scrolls, or of ancient Rome with their earliest lending libraries (Casson, 2002). These ancient designers clearly demonstrate the importance of a thorough literature review by the effort that was required to achieve it. Most design today is not invention but innovation of an earlier design that is found by carrying out a thorough literature review. We, as teachers must pass on to our students the importance of a thorough literature review. To be thorough requires researching areas that may appear completely unrelated to the planned design project. To illustrate, a well-known brand of washing powder advertise that it cleans using the power of oxygen. This appears to be a rather spurious claim. While researching, would it be obvious to research fishing boats, no, even though fishermen for years have cleaned their dirty clothes by putting them in a net over the rear of the boat (Sailing a Catamaran, 2021). The churning of the propeller releases oxygen which cleans the clothes. Something totally unrelated to washing powder, fishing boats, provided a valuable clue to the researcher. The importance of a thorough literature review and how to achieve it must be taught to our students.

An important part of any literature review is the accumulation of knowledge. Along with researching the latest knowledge, it is important to look at historical knowledge. Hero's design was built on the knowledge of Philo's design, Newcomen's design of his 'Atmospheric Steam Engine' was built on the knowledge of Hero's design. James Watt's improved steam engine was built on the knowledge of Newcomen's design and so on. This process continues into our modern era. Even though we live in an age where knowledge, through the internet is at our fingertips, there are still areas that require the attention of teachers. Basic engineering knowledge, such as use of keyways, selecting bearings, difference between bolts and screws, identifying internal and external circlips etc. is accumulated by engineers everyday they are at work. This knowledge adds up to a vast library of knowledge and is sometimes referred to as 'experience'.

Part-time students at college or university, as an entry requirement, will be in appropriate employment in the mechanical engineering sector. They will be building their library of knowledge or experience every day in work, and at the same time, building their knowledge of complex engineering systems in their studies at college or university.

Full-time students at a college or university will also be building their knowledge of complex engineering systems in their studies. Their library of knowledge will be building, but at a much slower rate than part-time students. This has created a very large divergence in basic engineering knowledge between part-time and full-time students (Sole, et al. 2021).

As teachers, we learn to differentiate in our classes, to allow and accommodate the differences in our students. For design students, this must include the difference in basic engineering knowledge between part-time and full-time students?

Industrial Revolution, Industry 4.0

During the industrial revolution technological changes included new materials; new energy sources; new machines; work was organized into factories; new transportation; and increasing application of science by industry (New World Encyclopedia, 2018). During this period designers and engineers produced some of the world's greatest inventions and designs. The steam engine, telegraph, steam locomotive, submarines, telephones, steamboats, transatlantic cable, the airplane, and the light bulb (Engineering Daily, 2017).

The first industrial revolution, in the eighteenth century started with the introduction of the steam engine which made many manual jobs, mechanized. This was followed by the second industrial revolution in the twentieth century which was driven primarily by electricity. Design during the first and second revolutions was an in-house affair, each company having their own, small design departments. The third revolution, which is ending, was due to the use of electronics and computer technology for automation in manufacturing. Design during the third revolution began with much larger design departments with hundreds of designer's working on more and more complex designs. With the introduction of computers, the design departments became smaller, but the complexity of designs became larger. We are now entering the fourth industrial revolution, also known as Industry 4.0, which uses advanced manufacturing and engineering. The speed of this revolution is unprecedented. Previous revolutions evolved linearly, the fourth is evolving exponentially. The breadth and depth of change will transform entire systems of design, and manufacture (Kenett & Swarz, 2020). This revolution has heralded the design and manufacture of things never even imagined. The mobile telephone with instant internet access, automated factories, large commercial aircraft, communication satellites, self-driving automobiles, and global positioning systems, are just a few of the benefits from the fourth revolution (Pal, 2008).

The challenge for teachers is keeping abreast with the changes. Links with industry help, but unless these companies are cutting edge, world leaders, this source of information will always be slightly behind the latest developments. Trade and journal papers provide information on the latest developments. Research links with industry are a very good way to maintain current knowledge. Current knowledge requires that teachers maintain continually updated course notes with student being made aware that this is the latest data/knowledge they are receiving.

The Age of the Airships

Moving forward to the 20th Century. On 24 August 1921, the airship R38, with a crew of 49 on board was practicing turning trials over the Humber Estuary, UK. This involved turns at full helm and full speed. It suffered structural failure and broke in two, killing 44. During the subsequent investigation it was revealed that responsible officials had made no calculations whatsoever of the aerodynamic forces acting on the airship in flight. No one was sacked over it, or even suffered censure. This same team was entrusted later to the building of the R101, see Figure 3.

In 1924. a small team of 6 - 8 engineers came together to begin design on another airship, the R100. The team was led by Mr. B.N. Wallis, made famous later during World War 2 for designing the Wellington Bomber, the bouncing mine that destroyed the great dams of Germany, and finally some of the largest bombs of the war, Tallboy (6 tons) and Grand Slam (10 tons). The current design practice was for engineers and designers to devise solutions to problems. These solutions were recorded on paper using 2D drawing methods. Due to the increased complexity of the designs 'Calculators', specialist individuals were employed to calculate the stresses acting on the airship frame. This process could take up to 2 - 3 months and began by estimating the forces in the frame, then re-calculating the forces until a satisfactory resultant of zero was obtained. A double check on the results was then made, using a different method. If the calculations were correct, they too would give a resultant of zero. These hand calculations could fill 50 pages of foolscap (Shute, 1956). This is an iterative mathematical procedure in which an approximate solution to a problem is initially guessed and then fed into an iterative formula which reveals a more accurate solution (Hawes & Abinett, 1981). This airship, during its trial flights proved to be successful and safe. The R100 clearly demonstrates the importance of stress calculations followed by re-calculations using different but complimentary methods until satisfactory results are obtained.

Let us now return to the R101.The work on it was finished on the 12th October 1929. Two days later it slipped from the mast at Cardington, UK, on its maiden flight. After several flights it was decided that the lifting capacity of the airship required increasing, and at the same time to initiate as much weight saving as practical. Were these major changes due to a lack of pre-manufacture calculations? The decision was made to insert an extra section in the center of the airship which would increase the length by 53ft from 724ft to 777ft. The gross or total lift was increased to 167.2 tons, with the fixed weight now 117.9 tons, giving 14.4 tons increase in disposable lift to 49.3 tons (Stewart, 1994). After brief trials and a Certificate of Airworthiness that was issued hours before departure, the airship left for a journey to India. In poor weather it made it just south of Beauvais, France where it crashed killing 48 out of a compliment of 54.

The two tragedies of the R38 and R101, both designed by the same team which was known to be lacking in accurate or any calculations, highlights the importance of calculating the forces acting on a component. Today, computer software provides the tools necessary to calculate these forces. A component can be modelled virtually using 3D software. The forces acting on the model can be applied and Finite Element Analysis (FEA), in a fraction of the time, will calculate the forces (Hutton, 2004). But much more is required. Using 3D modelling software is not difficult to learn. Understanding its limitations takes much longer. Students must be aware of the requirement to validate the setting up of the software so that correct results are obtained. SolidWorks, a 3D modelling supplier provides 142 validation examples to help the user understand these limitations (SolidWorks Simulations, 2019).

To back up modern day FEA simulations, calculations based on accepted industry calculations are also necessary. When the R100 was in its design stage, ‘Calculators’ spent months calculating the effect of forces acting on the airship frame. They backed up their calculations by checking them using different methods. Our students should be taught to calculate then recalculate using different methods. Students often have enough difficulty using one set of calculations and getting them to match the results from FEA. When they do not match, which is right, and which wrong? The more methods students can use to calculate stress the more accurate will be their results. As an example, a basic, but extremely important calculation is that of stress in beams. What methods are students taught? Macaulay’s, Castigliano’s, Superposition, and Elastic Energy. Any or all these methods can be used to determine the stress in a beam, then recheck it and finally to confirm the results using a validated FEA method.

Concorde

The design and manufacture of Concorde (Figure 4.) was an early example of international cooperation. On the 5th November 1956 the first of 7 meetings took place of the Supersonic Transport Aircraft Committee. Several technical subcommittees each had 12 meetings, Air Registration Board, Aircraft Research Association, National Physical Laboratory, and College of Aeronautics. Finally, Specialist Working Groups met many times. By 29th November 1962 the historic Anglo-French Agreement to build Concorde was signed (Owen, 2001). This agreement provides details of the responsibilities to design and manufacture each country was to assume. Five main areas of equal sharing were stipulated, Structure, Systems, Aerodynamics, Strength and Aero-elasticity calculations, and Weight and Center of Gravity estimates. Later, the aircraft ancillary systems were allocated to each country. A 50/50 split of these areas was the aim. The design process followed a traditional path of design, check, detail design, prototype, test, redesign if required until a desired solution was found. The collaboration allowed each country to designed and manufacture components separately, thus reducing the possibility of both countries design having the same faults, if any. This design process achieved similar results as using 'Calculators' when designing the airships. Two different determinations of forces to reduce or eliminate potential errors.

Nothing like Concorde had ever been attempted before. The technical problems were immense. All parts were designed using 2D systems to represent 3D parts. Only the most basic computer systems existed, so nearly all calculations were carried out manually. The designers could only dream of FEA and virtual mock-ups. Therefore, as Mr. James Hamilton, the Director-General (Concorde) at the Ministry of Aviation said 'This airplane was the most tested airplane of all time. We had rigs for everything,…..we were putting all the systems together under real flight conditions for the first time, you can never be quite sure' (Owen, 2001).

The effect of coordinating the United Kingdom and France's input, designing, and then redesigning, inflation, devaluation, changes in exchange rates, testing, flight testing was shown clearly in the increasing costs. In 1962 the estimated cost was £150-170m. By 1979 the estimated cost had spiraled to £1,129m.

Concorde is an example of teamwork and cooperation between two countries. Regular meetings were held, and clear lines of responsibilities decided upon. The design was world leading which made the development costs extremely high. Software FEA simulation was not an option the Concorde designers had. Even if software FEA simulation was available, it would not have helped with the problems the designers were facing. Software FEA simulation is very good for known problems, problems that the computer programmers could include, but no good for cutting edge design. It is impossible to program any software with data that is yet to be recorded. When teaching design to students, it is vital that they understand fully the software they are using, but more important, to understand what the software is not capable of.

Concorde was one of the first examples of international cooperation and highlights the importance of open communication between design teams, clear allocation of responsibilities and the importance of regular meetings. Colleges and universities should teach students how to work as a team, the importance of regular meetings, how to make clear allocation of work, how to manage a team when things do not go as smoothly as expected.

Boeing 777 – The Computer Age

Design and manufacturing engineers in the early days at Boeing worked around 50 yards apart from each other. When there was a problem in the factory, the engineers went down and looked at it and said, 'Well, you'd better do this.' As the scale of the company grew, designers and manufacturers began to physically drift apart, little enclaves developed. Structures went in one place, air conditioning another. The culture of the company became 'Us and them' (Sabbagh, 1996). This culture was not conducive to efficient design and build.

When Boeing was preparing to design and build a new airliner, the Boeing 777 (Figure 5) they went on a visit to Japan and came across a system called Design-Build Teams (DBT) (Glende, 1997). For the first time in Boeing's history, these DBT would include not just design and manufacturing engineers, but also representatives from the airlines, maintenance organization, marketing, and many others. The design teams worked concurrently on parts, which reduced later modifications, increased efficiency in building and installing those parts. At their peak, Boing had 238 DBT's (Design Philosophies, 2021) (Sharma & Bowonder, 2004). A DBT, working for example on engines would in practice, be working as the early designers and manufacturing engineers in Boeing had but with increased efficiency due to the variety of other representatives in the teams (Birtles, 1998).

For the first time, computers were powerful enough to design 3D parts virtually. Computer-graphics Aided Three-dimensional Interactive Applications (CATIA) format was used. These virtual parts could then be assembled using a second program, Electronics Preassembly in the CATIA (EPIC). Boeing distributed 2,200 computer terminals among its DBT's. All this was connected to the world's largest grouping of IBM mainframe computers (8 off). This system allowed manufacturers in Japan, engine makers in the United States of America and the United Kingdom immediate access to the data.

During the planning phase, justification for the use of a very expensive computer system to design the aircraft was required. The planners looked back at a previously manufactured aircraft, the Boeing 767. They concentrated on certain aspects of its design such as the doors. On this aircraft there was two doors, passenger, and cargo. The doors, during the design phase required 1,341 modifications. The planner's put a dollar value on these modifications and came to a staggering total of $64 million. To put this amount in context, a new Boeing 767, back in the 1970's cost $100 million. When the doors on the new Boeing 777 were designed by two DBT's using the new CATIA and EPIC systems the errors were reduced by 95% which also equates to similar financial savings. Another example was using CATIA and EPIC to check 20 pieces of the flap system. The computer ran 207,601 checks for interferences between parts. A total of 251 interferences were highlighted. These were printed out and at the next DBT meeting it was decided who would be responsible for which interference, saving any possible duplication.

The importance of modern computer systems is emphasized by the Boeing 777 design and manufacture. Today the CATIA and EPIC systems are combined into one system making for even more savings. The importance of design being a team operation was shown by using Design-Build Teams (Sabbagh, 1996). Computers made the complexity of design easier to handle but required teams of specialist to know how to use them effectively.

Conclusion

Looking through this brief history of designing complex components it becomes clear that our ability to design ever increasing complex systems with relative simplicity was built on the shoulders of design engineers who were giants in their fields. Philo's and Hero's Force Pump reminds us of the importance and simplicity of communication using sketches. Computers cannot compete with the simplicity and speed of pencil and sketch pad, yet. To get the most benefit from a literature review, be thorough, and think 'outside the box'. The obvious searches may not always be the ones that provides the most helpful information. The crashes of the

R101 and R38 demonstrate what could happen when designing an airship, with little to no calculations. Compare these with the successful R100, where the stresses in the rigid frame was fully calculated, and once calculated, the importance of double-checking the calculations using a different method. Getting the balance right between software calculations and manual calculations is critical. Concorde's technical design, which still marvels today, must be weighed with the astronomical costs involved in testing and proving not just once but twice for each country involved. The collaboration between two countries in a design and manufacture project identify the importance of regular meetings, and clear allocation of responsibilities. This is even more important today when collaborations between many countries in the design process is normal. The beauty of 3D modelling and advantages in time and money that the Boeing 777 benefited from are important factors but must be balanced with the need to double check calculations as previously mentioned. The strengths that come from working as part of a design team are critical to the success of complex designs today. The Internet takes team working to a planetary scale. Let us provide our students with the necessary team skills to make the most of this development.

We do not have to invent something new or design a world breaking innovation to improve the way we design. By looking in the past and reminding ourselves about things already proven to work we can improve our designs for the future. This paper reviewed just a few processes from the past. These processes are as valid now as they were then. They worked, complex designs for their age were produced. Modern designers just require reminding that these tools are there, proven, tried, and tested.

References

Birtles, P. (1998) Boeing 777Jetliner for a New Century. MBI Publishing Company, USA. ISBN 0-7603-0581-1

Casson, L. (2002) Libraries in the Ancient World. Yale University. United States of America. ISBN 0-300-09721-2

Ceccarelli M. (2021) Challenges of Mechanical Engineering and in IFToMM: Yesterday and Tomorrow. Gears in Design, Production and Education. Mechanisms and Machine Science, vol 101. Springer, Cham. https://doi.org/10.1007/978-3-030-73022-2_3

Design Council (2018) The Design Economy: New Design Council Evidence on the Value of Design. Available at: https://www.designcouncil.org.uk/news-opinion/design-economy-new-design-council-evidence-value-design (18 July 2021)

Design Philosophies, (2021) Boeing 777 Design Philosophies DB Teams.[online] Available from: https://www.mura.org/websites/me39c.me.berkeley.edu/ Spring97/ Projects/b777/dbt.html [Accessed 3 October 2021]

Dieter, G. Schmidt, L. (2009) Engineering Design. 5th Ed. McGraw-Hill. New York, United States of America. ISBN 978-0-07-339814-3

Engineering Daily (2017) Engineering Inventions Created During the Industrial Revolution [online] Available from: http://www.engineeringdaily.net/engineering-inventions-created-during-the-industrial-revolution/ [Accessed 24 October 2018]

Friend, D. (2018) Virtual Reality and its Applications in the Mockup Process: A Case Study. California Polytechnic State University, San Luis, Obispo, CA.

Glende, W, L. (1997) The Boeing 777: A Look Back. [online] Available from: https:// www.sto.nato.int/publications/AGARD/AGARD-CP-602/08CHAP05.pdf

[Accessed 3 October 2021]
Hawkes, B. Abinett, R (1984) The Engineering Design Process. Addison Wesley Longman Limited. ISBN 0-582-99471-3
Hombergen, S. Ploeg, C. (2018) The Virtual Mockup: Parametric Design and Optimization of Complex Faheade Panels in Virtual Reality. [online] Available from: https://www.autodesk.com/autodesk-university/class/Virtual-Mockup-Parametric-Design-and-Optimisation-Complex-Faheade-Panels-Virtual-Reality-2018 [Accessed 18 July 2021]
Hutton, D. (2004) Fundamentals of Finite Element Analysis. McGraw-Hill. New York, United States of America. ISBN 0-07-239536-2
Kenett, R. Swarz, R. Zonnenshain, A (2020) Systems Engineering in the Fourth Industrial Revolution – Big Data, Novel Technologies, and Modern Systems Engineering. 1st ed. John Wiley and Sons.
New World Encyclopedia (2018) Industrial Revolution. [online] Available from: http://www.newworldencyclopedia.org/entry/Industrial_Revolution [Accessed 24 October 2018]
Owen, O. (2001) Concorde, Story of a Supersonic Pioneer. NMSI Trading Ltd, Science Museum, London ISBN 1 900747 42 1
Pal, S (2008) 21st Century Information Technology Revolution. [online]. Ubiquity, Volume 2008 Issue June Available from: https://ubiquity.acm.org/article.cfm?id=1399619 [Accessed 26 October 2018]
Pramod, R. Raju, P.K. Sankar, C.S. (2010) Improving Mechanical Engineering Education Through Use of case Studies. Proceedings of the ASME 2009 International Mechanical Engineering Congress and Exposition. Volume 7: Engineering Education and Professional Development. Lake Buena Vista, Florida, USA. November 13–19, 2009. pp. 271-279. ASME. https://doi.org/10.1115/IMECE2009-12872
Sabbagh, K. (1996) 21st Century Jet. The Making of the Boeing 777. Pan Books. London, United Kingdom.
Sharma, K, J. Bowonder, B. (2004) The Making of Boeing 777: A case Study in Concurrent Engineering. International Journal of Manufacturing Technology and Management https://doi.org/10.1504/IJMTM.2004.005389
Selgin, G. Turner, J. (2020) Strong Steam, Weak Patents, or the Myth of Watt's Innovation-Blocking Monopoly Exploded. [online] The Journal of Law and Economics. Available from: https://www.journals.uchicago.edu/doi/abs/10.1086/658495 [Accessed 8 January 2021]
Shute, N. (1956) Slide Rule – The Autobiography of an Engineer. Readers Union William Heinemann
Sole, M. (2021). 'Design Education - A Reversed Method to Fill an Information and Knowledge Gap Between Full-Time and Part-Time Students'. The 23rd International Conference on Engineering Design. Gothenburg, Sweden, 16-20 August. Scotland: The Design Society, pp. 1-9.
SolidWorks Simulations (2019) SOLIDWORKS Simulation 2019 Validation. Available from: https://www.solidworks.com/sites/default/files/2019-04/VPCSEnglish2019.pdf [Accessed 30 December 2020]
Stewart, S. (1994) Air Disasters – Dialogue from the Black Box. The Promotional Reprint Company Limited. Australia. ISBN 1 85648 182 4

Stroud, I. Hildegarde, N. (2011) Solid Modelling and CAD Systems. How to Survive a CAD System. Springer-Verlag, London. DOI 10.1007/978-0-85729-259-9

White, A. (2014) Early Newcomen Engines on the Warwickshire Coalfield, 1714-1736. [online] Available from: https://doi.org/10.1179/tns.1968.017 [Accessed 8 January 2021].

Alone in the sustainable wilderness; transforming sustainable competences and didactics in a design for change education

Thomas Østergaard, VIA University College, Denmark

Abstract

According to UNESCO (2012) pedagogies associated with Educations for Sustainable Development (ESD) should spur and inspire students to think critically, ask questions and reflect. The assumption is, that pedagogies are moving towards student-centred participatory learning. Still, the educator is at the core of the transition towards developing ESD's, so changes of the educators' worldviews and practices are emerging. The educators' competences and knowledge on ESD-development becomes central as the question of the what and the how the students are taught becomes more pressing.

Today many sustainable educations still have a high focus on systemic issues (external systems); politics, technology, or socioeconomic structures (Parodi & Tamm, 2018, Wamsler, 2019) and lately the UNESCO (2021) has stressed the need for adapting cognitive, transformative, personal, emotional, dimensions of learning into ESD.

In a transformative learning setting the educators should provide real-heartfelt experiences generating the students with capacities to reflect critically on both systems and personal design practice methods and help them aligning their methods with their personal emotional values. In doing so, the educators feel left "alone in the Wilderness" and research in the personal dimension of sustainable transformation and connection of this to ESD's is scarce (Parodi & Tamm, 2018, Wamsler, 2019).

On this backdrop, this article provides a reflexive case study of a BA level course on "Design for Change" performed from 2019 – 2021 using transformative learning practices and the connected interventions in the form of a reflection tool, the Decoding Creativity Tool (DCT). The data was collected to discover if and how the students could enhance personal sustainable competences using transformative learning focusing on the personal emotional and creative development and awareness, reflection tools and "visiting" methods.

Implementing transformative learning and ESD's into educational practices requires radical revisions of the design education system, managerial strategic commitment and involves many levels of the HE's. It requires both internal and external collaborations for the design educations and could involve developing new didactics and methods where ideas can grow. (Barth & Rieckmann, 2012).

Keywords

Design Education, Design for Social & Sustainable Innovation, Entrepreneurship, Design Didactics, Education for Sustainable Development

Introduction

We are faced with an unprecedented and huge learning challenge at every level, in which educational policy and practice need to play a pivotal role. How do we 'reorient our systems of knowledge creation and education'? How do we ensure that education for these extraordinary times can manifest a culture of critical commitment—engaged enough to make a real difference to social–ecological resilience and sustainability but reflexively critical enough to learn from experience and to keep options open into the future? (Sterling, 2016, p. 212)

88% of the Danes think it highly important that young people receive proper and coherent education in how we as a society handle the climate challenge, according to a recent survey performed by the Climate Barometer 2020 (Thinktank Concito, 2021). With numerous initiatives forming over the years such as A Nordic Textile Strategy initiated by the Nordic Council for Ministers targeting increased collection, sorting, reuse and recycling, Global Fashion Agenda or Mistra Future Fashion research program from Mista and RISE Research Institute of Sweden, the intention is to bring together research, business and governments for a unified approach to accelerate the transition towards sustainable development and circularity in the fashion industry. However, little focus has been placed on the educational feature. As for Denmark, it ranked second in 2019 on the Eco-Innovation Index, an initiative of the European Commission aiming to measure and evaluate eco-innovation performance across the EU Member States at a research business' and policy level (European Commission 2021). But advancements are developing at a painfully slow pace as translating theory into practice is highly intricate and requires many iterations.

The Nordic Countries are often considered to be pioneers in the sustainability agenda and research provided by the international collaboration of design-schools "Fashion-Seeds, 2020, Education and Research, The Benchmarking Report" somehow confirms this position. With 17 publicly funded Higher Education Institutions (HEs) within the fashion and textiles disciplines, either deriving from design, engineering, business or arts and craft traditions many of these now have academic sustainability research and educational offers around ESD.

"Fashion Seeds, 2020" describes the development of sustainable curriculum in the Nordic countries; "To some HEIs it is still a challenge to integrate progressive learning of the subject within their full range of BA and MA programmes. … going from individual courses focusing on selected sustainability aspects to a more holistic and institutional perspective, in some cases supported, in others imposed by management." (Ræbild, Riisberg & Hasling, 2019, p. 61).

Even as the "Benchmarking Report" finds the level of teaching in ESD at the design-schools in the Nordic Countries well integrated, recent studies show huge gaps in the practice of the design-students in social, sustainable, and complex challenges. (Østergaard, T., 2018, Østergaard, 2019, Dan, M. C., & Østergaard, T., 2021) One of the leading design-didactics, Ken Friedmann, stresses that many European design-graduates finish their studies with a narrow concentration in design skills and lacks competencies to cope with the complex reality. (Friedman, K. 2019) In this way, what and how they are taught becomes essential. But it also becomes central if the educators have the right competencies and didactic understanding to teach the students sustainability competencies. (Sterling, 2001, UNESCO, 2017, Sleurs, 2008)

The call from outside for teaching ESD has created a variety of didactic approaches to teaching at HE's. It requires selecting decisions of cases, collaborating partners, didactics, and evaluation tools, which are all political choices made from the educators' perspective. Teaching sustainability is thereby fundamentally about how the educator perceive the reality and engage with or envision societal values. (Parodi and Tamm, 2018) In this way the use of learning theories which enables the student's ability to challenge their personal perceptions of the World through new ways of thinking and critically reflect on their learning process may differ in practice. But lately research indicates that "Transformative Learning" can be used as driver for sustainable change. (Illeris, 2014c, Vare, 2018, Mulà et al, 2017)

An example of the use of transformative learning principles in ESD can be found the Rounder Sense of Purpose-project (RSP). In 2019 the three-year EU-funded project RSP (working since 2015 to develop an accredited framework of sustainable competences) presented 12 key competencies for ESD. The project results showed twelve key competences of which three were especially highlighted. These three competences are the "basics" of sustainable competences and the report encourages educators to focus on developing the systemic, the critical and the anticipatory thinking competences. (Vare, 2018)

In this way, the RSP project stresses the importance of the educator having a critical understanding of sustainable development as well a profound grounding in the pedagogy of Education for Sustainable Development (ESD). The Rounder Sense of Purpose was designed to help educators find ways of using new didactic methods on one hand and at the same time making new contributions developing new methods. The RSP framework presents twelve educator competences as the basics in a learning process and a method to for educators to assess their ESD capabilities. Like the other reflective and transformative Decoding European Creative Skills project, (DECS) (Martinez-Villagrasa et al, 2018) each competence has several (three) learning outcomes and under these and underpinning components. As the project understands "teaching as an art" – these are presented on an interactive artists palette and by clicking on the competence you find a link to activities developed to enhance the specific competence. The RSP framework is presented in a matrix of 12 competences arranged in the same three columns as the UNECE framework: holistic approach, envisioning change and achieving transformation. The RSP competence-table proposes a progress which the educator could follow: (a) Integration—using knowledge from different dimensions, looking at interconnections and cause-effect relationships. (b) Involvement—building this understanding into their personal sense of commitment. (c) Practice—combining the two stages above in their practical work as an educator. (d) Reflection—evaluating the process and results of their work, assuming responsibility, and taking decisions before repeating the process in an iterative learning loop.

But overall, the RSP framework encourages educators to develop a transformative, action-oriented, pedagogy which will encourage the students in involving / participatory, creative, systemic, critical reflecting actions. (Vare, 2018). In order to understand the principles of developing sustainable competences in the DFC, the course will be analysed into the context of the principles and compared to the work with the Decoding Creativity-tool (DC-tool).

The Decoding European Creative Skills (DECS) project will be highlighted as another example and a practical tool for enhancing the students creative and sustainable competences. DECS was a co-funded project by the Creative Europe Program of the European Union lead by ELISAVA, School of Design & Engineering together with Fachhochschule Salzburg University of Applied Sciences and Eindhoven University of Technology. The aim of the project has been the mapping and categorization of a variation of creative skills which defines the knowledge of present designers and designers-to-be. (Martinez-Villagrasa et al, 2018)

DECS poses questions on the 21'st century design student's competencies and the "gaps" discovered between the research findings and the wishes to encompass future social, technological and environ-mental challenges and presents the notion that creativity is a multidimensional construction connected to many other competencies and not an autonomous or isolated skill. The methodology identified a list of ten competencies and 20 dimensions of these, which have been used to create a radiograph on the model, -related to the creative process. In this regard the DECS project and the DC-tool will be analyzed in comparison with UNESCO's canonized eight competencies applied to the students in the DFC course. The DECS approach is used as an example out of many on how educators can make the students reflect on own competences, worldviews and future expectations and thereby support the student in his/her own personal development and performance.

In the DECS project, the researchers created "The Creative Competencies Dictionary" and thereby invited designers to self-reflection and insight into the practice and skills for design in the creative process giving the teachers of design and helping the students to understand or even improve their own creative competencies.

By adding the CDT and using the Dictionary as a theoretical backdrop the educators can have a tool to discover individual gaps and potentials of the students' competencies as well as their work behaviour and thereby providing a self-assessment tool for universities to use also in developing educations for specific sectors. To the Professionals the tools can be used to detect and work on the progression of improving competencies within the company, when hiring or developing employee-strategies and personal development tools. Finally, the DECS project and the CDT provides new knowledge – a common language (grammar and a dictionary) and research on the creative competencies of designers across disciplines and challenges across Europe.

Still, a definition of competences relies on an interlinked complex of knowledge, skills, and attitudes that enables the performance of successful tasks and problem solving. (Barth, et al. 2007, Rauch & Steiner, 2013, Rieckmann, 2018, Sterling, S., 2016, UNESCO, 2021). The ESD discourse has presented eight key competencies of particular importance for thinking and acting in favour of sustainable development: 1. Systems thinking competency, 2. Anticipatory competency, 3. Normative competency, 4. Strategic competency, 5. Collaboration competency, 6. Critical thinking competency, 7. Self-awareness competency, 8. Integrated problem-solving competency. (Rieckmann, 2018, Sterling, 2001) If ESD courses and elements are only defined by lecturers it is still very unlikely students will feel the urge of commitment to work on SDG challenges, research shows. Didactic approaches to ESD reflect the latest trends in trying to develop "participatory" or "democratic" approaches combining active student involvement with empowerment (Barth et al. 2007, Mezirow, 2009, Østergaard, 2019).

As such, the DECS project, provides a vocabulary, a method for construing the 10 competencies and a relatively non-curricular informal tool for a continuing personal development proposes elements of the informal, “experiential learning” - developing a life competency - using intellectual, sensory as well as emotional responses in the assessment of the individual and the group in the process.

As the DCT provides a method to reflect on earlier experiences and the individual evolution of competencies. But as the vocabulary and the DCT-tool is a mixture of both knowledge based and experiential learning methodology it doesn’t quite meet the sustainability focused standards of the eight UNESCO competencies.

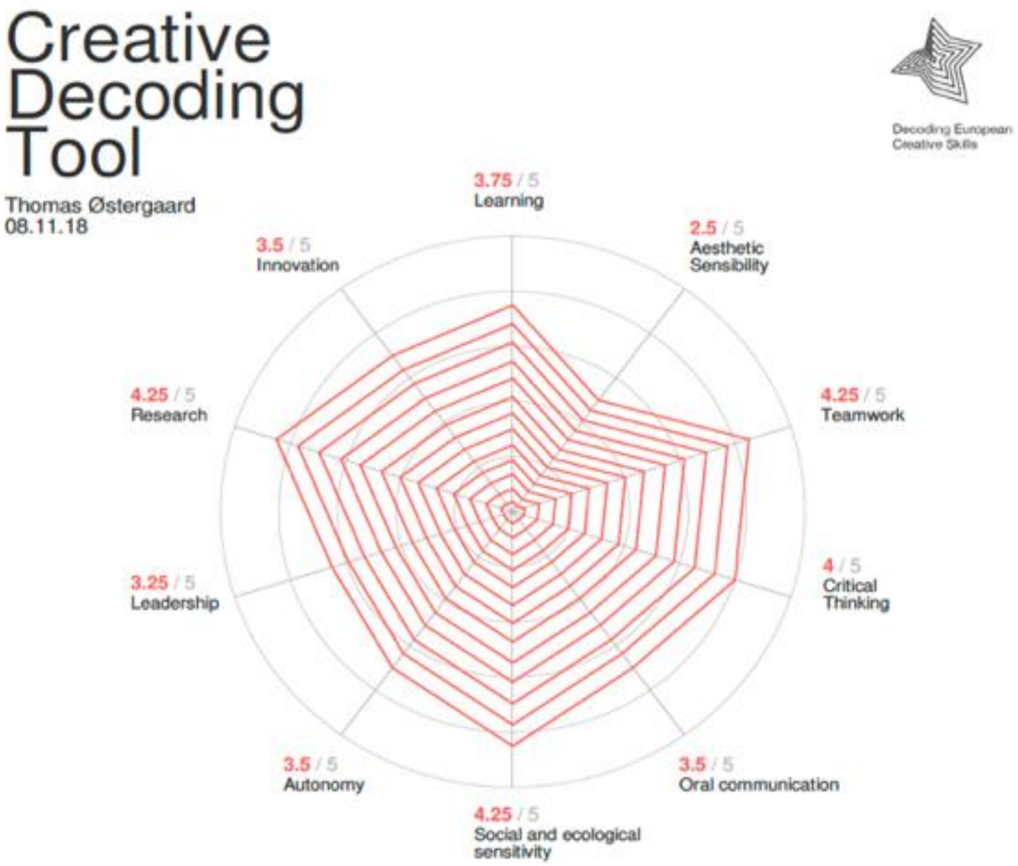


Figure 1; The radiograph on the behavioural models related to the creative process from the DCT applied.

On the other hand, as the DCT tool is a powerful competency development facilitator, it suggests a useful combination or use of the “regular” design competencies, such as “Learning”, (curiosity + knowledge internalization), Critical Thinking, (questioning + proposing), Oral Communication, (planning + charisma) Autonomy, (self-management + initiative) and of course Social and Ecological Sensitivity, (awareness + compromise) in a sustainability context. In a SE view, the DCT tool could help enhance the design-students self-awareness in relation to the UNESCO proposed competencies and add aesthetics and material-knowledge and science to the ESD competencies.

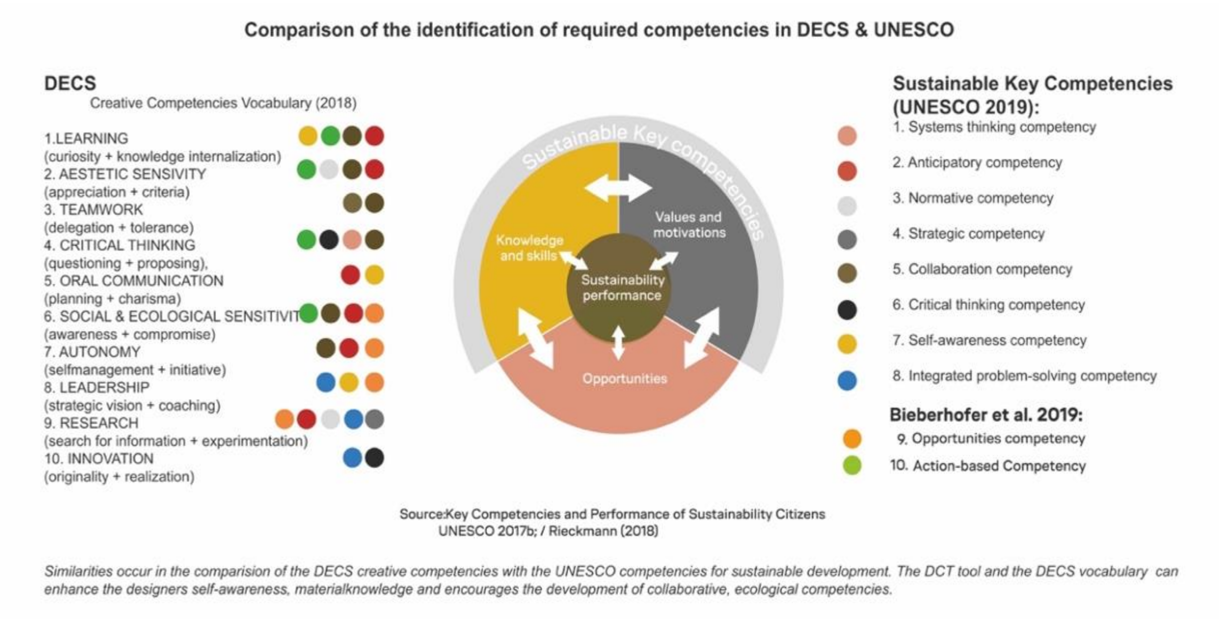


Figure 2; Comparison of the identification of required competencies according to DECS & UNESCO

The process of working with the development of the DFC course and the data gathered in interviews and surveys generated an opportunity to pose and respond the following question:

RQ1. Did participating in this course using the DCT Tool encourage a shift in the way students view their personal sustainable competences and possibilities in the industry and its systems? If so, in what way?

As the question has been the basis of the data analysis process, in helping to understand the experiences of the students surveyed it did not comply to the wish of investigating the role of the educator in transformative ESD. As a result, an additional secondary empirical literature review and research question was framed:

RQ2. How can design educators integrate transformative teaching strategies to encourage a shift in the way students view the sustainable future of their practice?

RQ3. How does the DFC course comply to the expectations of the educators sustainable competences and practices using transformative learning (RSP) in order to enhance the students' outcomes and learnings?

Findings

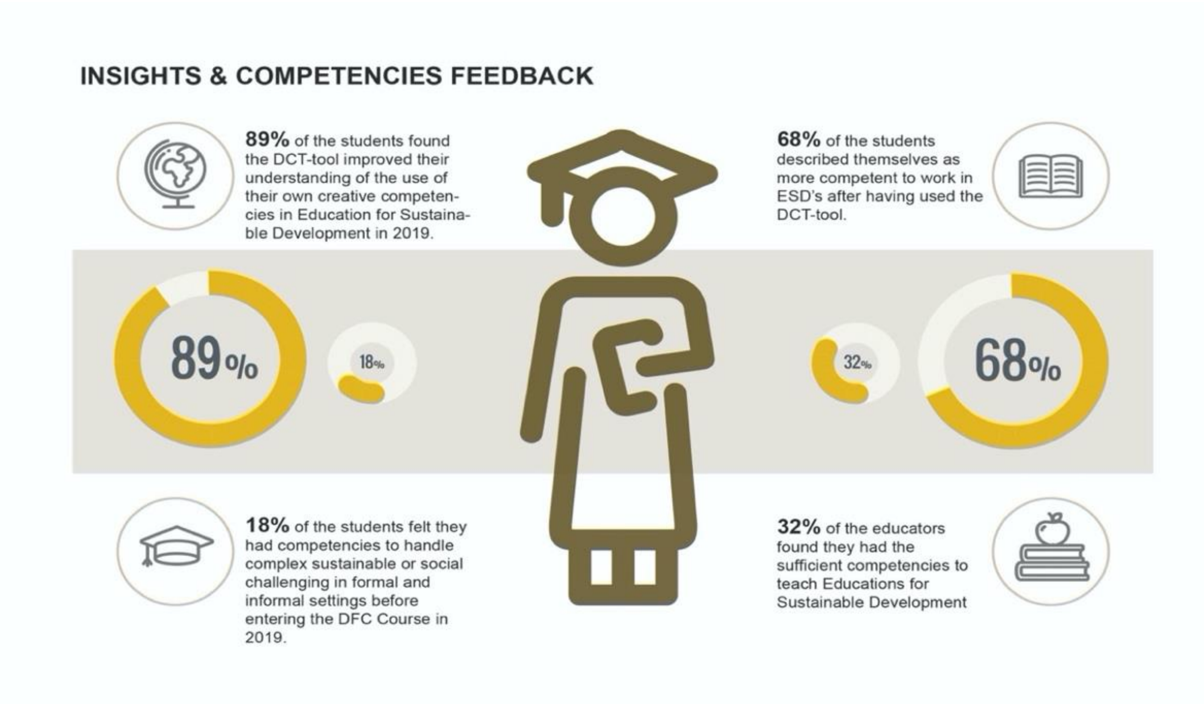


Figure 3; The findings and insights of the surveys

Methodology

This article uses data from two R&D projects, from 2019-2021; DECS and the Design for Change Course (DFC) at VIA Design, Denmark and research performed during the Decoding European Creative Skills project (DECS), adapted to the DFC Course in 2019-2021. As a result of the authors participation as an affiliated researcher in the DECS-program, from 2019-2021, the course integrated the use of the Decoding Creativity Tool and adapted the methodology and didactics of the Rounder Sense Purpose (RSP) (transformative sustainable learning) model and performed new semi-structured interviews and collected data from the course.

The study thus uses a mixed sequential method that combines the quantitative (studies) with semi-structured interviews - as qualitative research methods. (Lund, 2012, Silverman, 2014). The data analysis was performed in three phases. First, a survey was sent to 37 students of which 22 responded. Secondly a survey was sent to 30 educators at VIA Design & Business of whom 25 responded. As the studies mainly contained open-ended questions, the analysis was conducted through qualitative content analysis, where common themes were identified and coded. In the third phase of the sequential study strategy (Lund, 2012) nine semi-structured in-depth interviews were conducted with students who have completed the course using the DCT tool. Data was analyzed through thematic analysis (clustering), which made it possible to identify common and / or varying patterns in the responses.

The results of the interviews were then compared with the results of the study. For the DFC project, both qualitative and quantitative methods have been used and combined in this way to address both exploratory hypothesis generating questions and hypothesis confirmatory test questions. [27] The results can become complementary, providing a better framework for interpretation of the research area. The Qualitative data collection (semi structured interviews) consisted of 9 open in-depth interviews with students about their views on their personal sustainable competencies before entering the course, how the use of their creative competences could benefit their knowledge about sustainability and finally if the use of the DCT tool had changed their self-perception as capable of creating sustainable impacts.

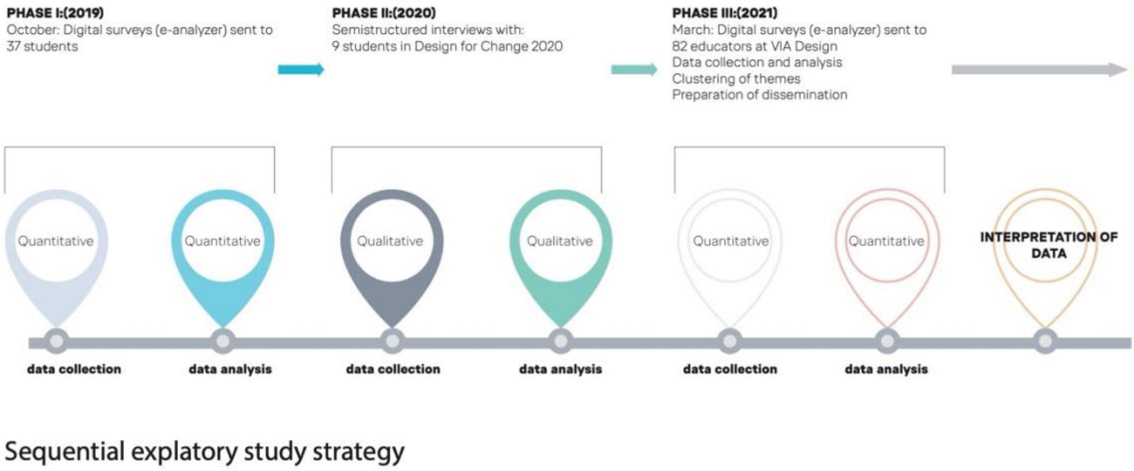


Figure 4: Timeline of the Sequential Exploratory Study, (Lund, 2012).

To bring knowledge on how the educators at VIA Design performs in ESD, a survey has been made to the educators at VIA Design (82 potential respondents) via the Enalyzer platform between February 24 and March 25, 2021.The data set came from a survey that consisted of ten questions with both dropdown and open-ended options for response. For this reason, the nature of the data and the type of research questions that the study addresses (Blaikie, 2003), the data has been analyzed using qualitative content analysis. The data analysis process consisted of coding and structuring codes into categories. Finally, the data was collated into thematic clusters.

The survey was conducted (dissemination and data collection) The survey sample consisted of educators from VIA University College, Denmark, from the Design and Business educational program.

The primary objective of the survey was to contribute to the development of new knowledge on sustainable development educational practices within ESD at VIA Design. Therefore, questions addressed: educational area of the respondent, the level of relevance that respondents find in ESD, Circular Economy and Circular Design teaching and their motivation, which means of understanding the complexity of CE would they prioritize in adapting the principles to their curricula, and how important it is to develop sustainable or circular competences amongst educators.

Delimitation has been set for this research as the surveys and interviews are only made with both educators and students from VIA Design. This effects the results as the “composition” of students and educators is very different from other design-schools. At the speciality, Design, Innovation & Entrepreneurship, the students seek admittance to the study with very various professional backgrounds. Students can have, like the educators a design-, a business-speciality, technical or arts-background. This makes the picture of "designers" blurry, but the definition of designers is here based on the notion that everybody who plans, performs, designs, and acts to change or make an impact on the world is a designer.

The research is also limited by the sample-size, as it is only based on 22 survey participants in the surveys to the students and only has 33 respondents from the educators, but it offers a brief glimpse on "how design educators can integrate transformative teaching strategies to encourage a shift in the way students view the sustainable future of their practice". Ideally, the research data would have benefitted in nuance and depth if it could have included more interviews - with educators as well. However, by combining interviews with students with survey analysis reflected on previous studies on the educators sustainable and Circular Economy competences this research gives a hint about the present potential of the role of the educators use of transformative learning methods in ESD.

Empirical Setting: Design for Change at a Glance

The Design for Change course at VIA Design has a collaboration with the Center for Assisted Living Technology (CAT) under the City of Aarhus, Denmark. CAT hosts the CareWare, and Teknologi i Praksis, (TiP) a social-economic business. It consists of two teams of students from Via Design, Innovation & Entrepreneurship, who collaborates and works across faculties and campuses. The purpose of the collaboration with CAT is to develop new services, designs and solutions as part of the DFC course. Moreover, the collaboration aims to increase students' understanding of how to use their professional and academic skills, how knowledge production is on a societal level, in a novel and unknown context developing solutions with users of welfare innovation. The co-design-facility for the students has been Godsbanen, an entrepreneurial site for NGO's, designers, and start-ups in Aarhus. To the students the possibility to see welfare design and technology innovation at TiP's showroom and working with their partners and experts in transdisciplinary units, increases the understanding of the great potential of this area, providing students to understand how projects are designed, the technology used, and products applied.

The products exhibited include a wide variety of the latest products within high tech welfare innovations, including measuring devices, digital solutions, smart textiles, electrical fold-up scooters as well as more "traditional" geriatric aids in wood, furniture, and new wheelchair concepts. In additions the students were introduced to other start-ups, social entrepreneurs or NGO's working with Sustainable Development. The following two pictures are from the open exhibition at TiP, showing students from the 2020 course discovering themselves through trying new technologies and examples of the latest welfare innovation.

Figure 5 Students exploring and learning from the curator in the exhibition, (Mie) about the exhibited examples of welfare design. Teknologi I Praksis is open for the public every day and visited by some 175.000 citizens and professionals per year.

At the DFC course the key design approach has so far been the Design Thinking (DT) method – also known as the Stanford D-approach used in close connection with the principles of Transformative Learning. This DT approach is often described as one of two innovations as management concepts, but it differentiates from the Harvard Business School approach (HBS) as it focusses on creativity and designing a product or service. Critics of the DT correctly stresses how distant or “staged” Design Thinking away from the actual users – design-sprints or design-workshops, offer suffer from hollowness and becomes more form than content - an empty shell out of its context. In the DFC course the DT-tool is used as a steering and process tool, enabling the students to understand which phases, participants, users and needs are in use, but supplemented with real visiting authentic and volunteer people connected to the challenge; arthrosis, sclerosis, or other challenges related to the Sustainable Development Goals, which they may address during their work. By combining it with transformative Learning principles it gives the students’ a wider and deeper understanding of the users.

The overall sustainable didactic framework for developing sustainable competences in the DFC is course is the Rounder Sense Project methodology, which will be used for interpreting the students’ evaluations in a later part. But the DFC course tries to address three innovative elements in order to enhance their creativity and innovation competences. DFC tries to:

1. Make the students understand the role and levels of knowledge production. By interacting with real-time people, expert-users, in unorthodox and still novel contexts

for the student, they experience how knowledge (including their own) can be produced at several areas and levels of society, and how different actors from different fields of society produce knowledge: technologically, artistic, economic, cultural, public, private, NGO-based knowledge. This is supported using both the Decoding Creativity Tool and the use of transformative learning principles, in which the students reflect on own learning and re-visits their own practices, products or ideas meeting new audiences, which at first seems "foreign" or external to the students' own academic practice, but at the same time creates value for the idea. (Parodi, & Tamm, 2018)

2. Make the students foster realistic imagination by "visiting" real, authentic people, companies, NGO's public institutions and citizens, who can alter, disrupt and surprise the students' prejudices or self-perception. This has shown to be both "mind-blowing" and generates a high level of uncertainty amongst the students, but it often makes the results personal, authentic and in accordance with the people the collaborate with – apart from generate creativity and new networks. (Parodi, & Tamm, 2018)
3. Foster the students' and thereby VIA's engagement and action in the society and provide frameworks for generating solutions to uncertainty through entrepreneurial didactics, self-reflection, and emotional awareness. (Parodi, & Tamm, 2018)

The DFC course has been nominated VIA education of the year in 2018 and 2019 and has been nominated for the national Tietgen Award by the Danish Society for Education and Business in 2021.

Pedagogic Principles of The Design for Change Course

The DFC course is generically developed over a period from 2014 – 2021 and in 2019-2021 consisted of "Transformative Learning Practice". Using the methodology of Mezirow (2009) and Illeris (2014a) in project-design and development. The basic ten pedagogic principles, as defined by Mezirow, (1997) could be described as the educator providing:

1. A disorienting dilemma which could be a setting in which the learner discovers own prejudices not to be applicable to a given new context or situation. This is often the case, when design students are expected to collaborate with the user-experts with psychical handicaps, sclerosis, or social issues. This dilemma is often challenging for some students, but also ignites the actual transformational learning.
2. Self-examination after a disorienting dilemma. On class the students will do a self-examination of beliefs and worldviews. Students reflect on their own background experiences and how this relates to the disorienting dilemma. This leads to the;
3. Critical assessment of own assumptions, taking a more critical and in depth look at their own past prejudices and practices. How does this impact our emotions and work? This hopefully creates a more unbiased worldview and opens the students towards new impressions. The next step is;
4. Planning a course of action, considering what learnings they now need and who they could collaborate with and how the;
5. Acquisition of new knowledge or skills to carry out the plan is needed. The students may have to re-think their own skills and competences and discover new perspectives from a design approach (Design Thinking) to enhance their learning and collaboration skills. After finding gaps or potentials in competences and learning the students' needs to

discover new functions, roles and learn about themselves and their competences by collaborating with other professions. By acting and interviewing other profession and reflecting on the DCT tool the students often experience new facets and capacities as well as new competencies they didn't know they had. Finally, the DFC encourages the students to believe in their newly discovered competences and;

6. self-efficacy and tries to support the construction of self-confidence and determination on working with sustainable changes.

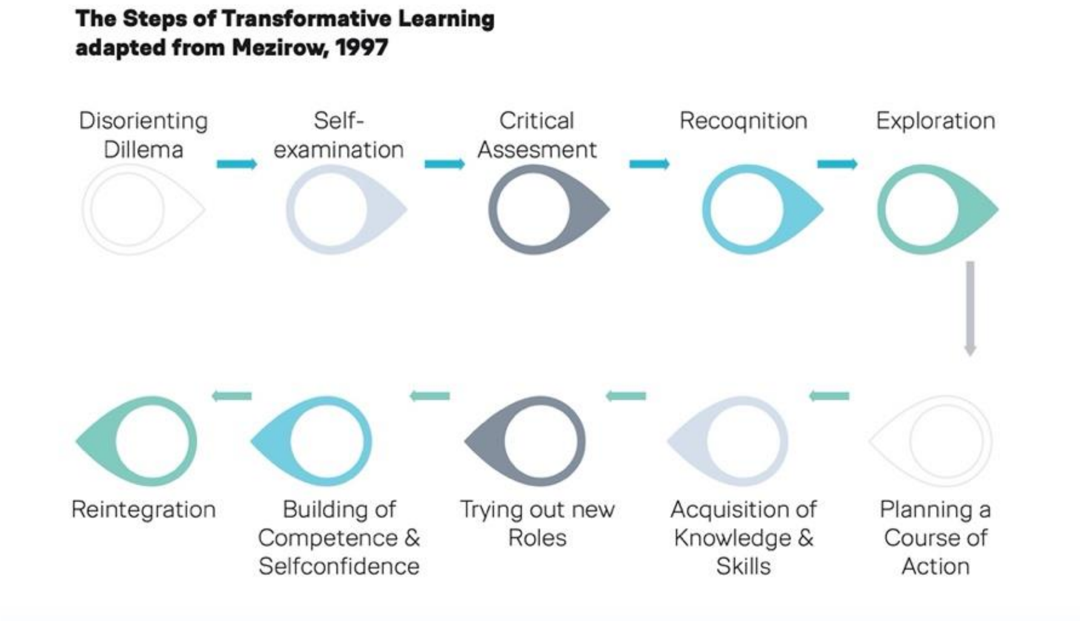


Figure 6: The steps of Transformative Learning, adapted from Mezirow, 1997

Research phase one: Design of survey sample

A survey consisting of seven questions was conducted via the E-Analyzer platform to 37 students of whom 22 replied in October 2019 after the DFC Course and with both dropdown and open-ended options to further elaborate on their answer. The data was analyzed using mainly qualitative content analysis but also had a data-driven approach. The survey sample consisted of students from VIA University College, Design, Entrepreneurship & Innovation at the DFC Course, Denmark, coming from both the Design and Business educational program. The questions worked as the framework for the following semi-structured interviews, trying to make the students reflect on; how transformative learning through the DFC worked; was the course different from other ESD courses, - reflection on the students self-assessment of sustainable competencies before, during and after the DFC-course, how the student used the DC-tool, if self-assessment, reflection and dialogue enhance personal and sustainable competences, which competences could be important to use in complex / sustainable design challenges and finally how the DC-tool helped the student to understand her/his creative competences and their relation to sustainable competences.

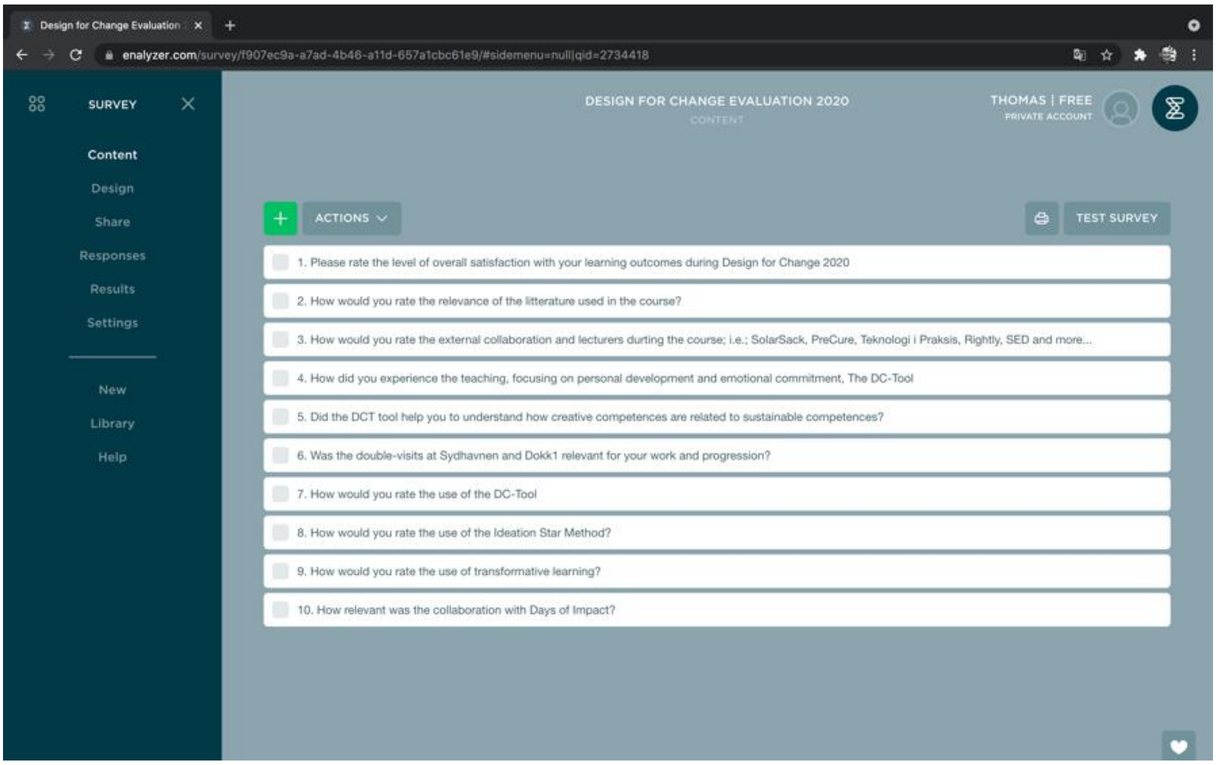


Figure 7: The overall question frame – evaluating the DFC Course, 2020.

Q4: How did you experience the teaching, focusing on personal development and emotional commitment, The DC-Tool

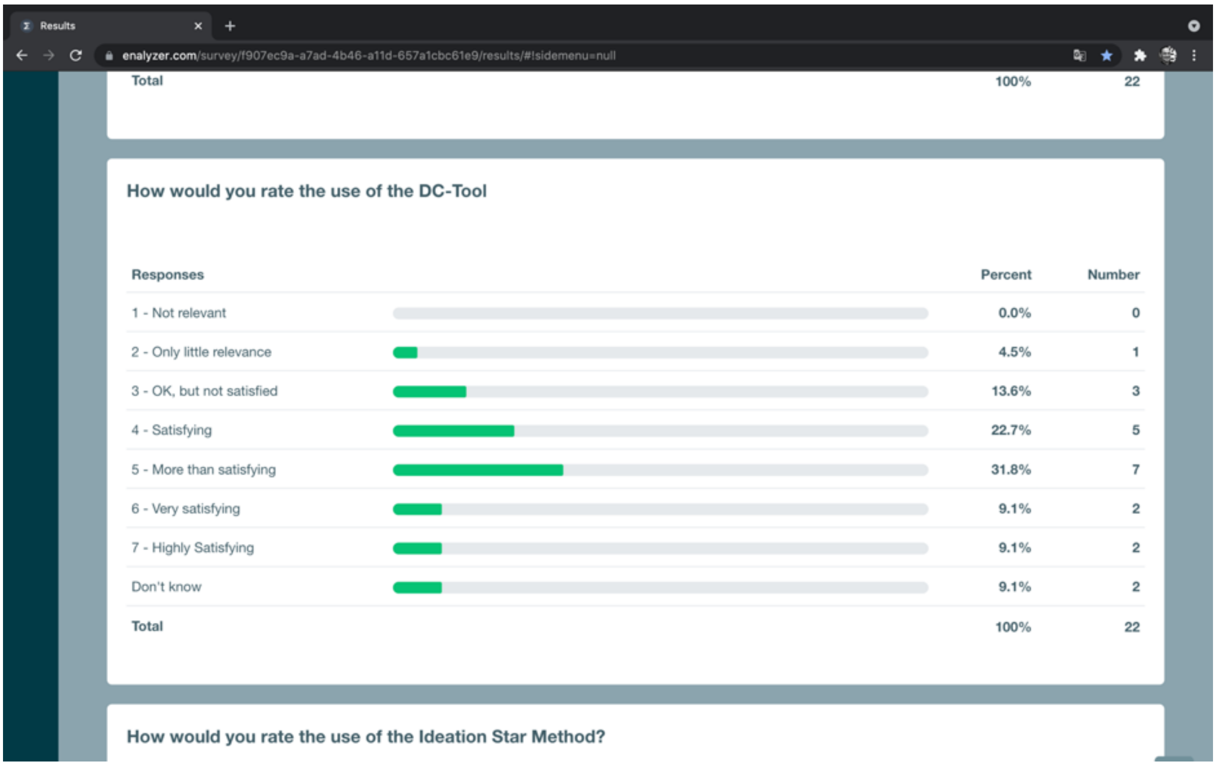


Figure 8: The majority of students found the DC-tool relevant and useful during the course.

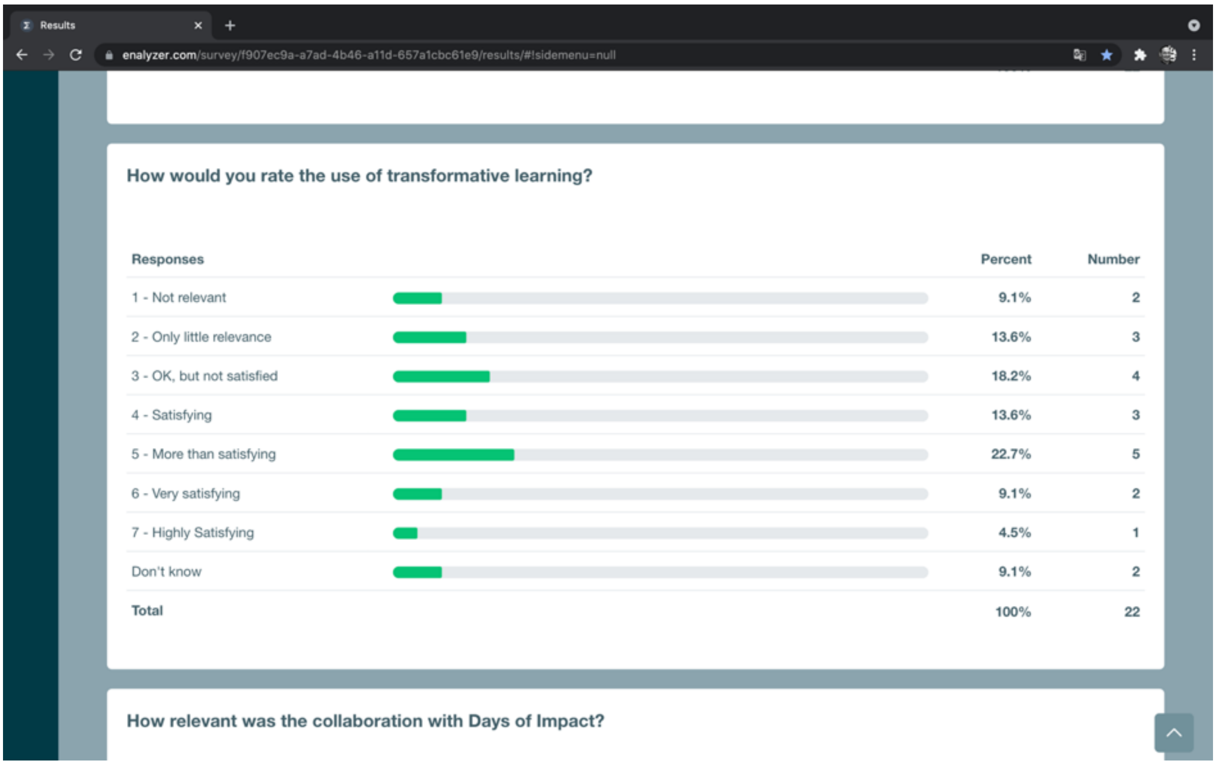


Figure 9: Not all the students complied to the idea of transformative learning.

Research phase two: Interviews, design & analysis

The nine interviews were conducted (qualitative data collection) in October 2020 via Zoom. This phase aimed to bring greater depth to previous survey results but also to compare and place within personal reflections from the students on their personal development in accordance with developing sustainable competences. The semi-structured interviews (Lund, 2012) had a duration between 40–60 min. The semi-structured expert interviews (Silverman 2014) had a duration between 60–90 min. The themes addressed through the interviews are listed below:

- Educational background information of the participant
- Evaluation of transformative learning through the DFC; was the course different from other ESD courses? If yes how?
- Reflection on the student's self-assessment of sustainable competencies before, during and after the DFC-course
- How did the student use the DC-tool?
- Does self-assessment, reflection and dialogue enhance personal and sustainable competences? If yes – how?
- Which competences are the most important to use in complex / sustainable design challenges?
- How did the DC-tool help the student to understand her/his creative competences and their relation to sustainable competences?

The interviews were recorded and transcribed. Then they were analyzed through thematic analysis. Relevant sample texts were selected, and a coding frame was constructed following both theoretical considerations and the materials at hand (Lund, 2012).

Results

The objective of the survey was to acquire new knowledge on how transformative learning methods using the DCT tool could enhance the student's reflection and self-awareness of sustainable competencies. The students were introduced to the DCT tool during the Design for Change course. It was used as a vocabulary and reflection-frame repeatedly for their performance and development as they were introduced to UNESCO's eight competences and the RSP model.

In the survey 89% of the students found the DCT-tool estimated they improved their understanding of the use of their own creative competencies in ESD / DFC. Before entering the course only 18% assessed they had the competencies to handle complex, sustainable, or social challenges. After having used the DCT tool and finished the course 68% of the students described themselves as more competent to work in ESD's.

Q 3: Do you feel more or less competent to work with sustainable challenges in the future after using the DC-Tool?

R4: "The Decoding Creativity Tool is for me is strong and nice tool to get a clearer perception of who I am, what is important to me and help to remind me later when I feel lost."

Q4: Does self-assessment, reflection and dialogue enhance personal and sustainable competences? If yes – how?

R1: "To me it was something new and scary. I was afraid I couldn't keep up with my own or the educators' expectations. I was a little anxious when I did the first try out – and when I saw the result, I was amazed that I have so many competences. I honestly didn't know my educational background, or my personality could contribute – but I think I have learned to believe in my potentials."

R6: "We had so much quarrel in the group regrading using the DC-Tool. Self-assessment was really not nice, I think. It became something un-cool in our group, as I think there was a competition going on about who was the best and most sustainable creative of us. That was not nice. But I think we could have gained more from it, if we had learned how to interpret it better on the class – but time was an issue. We didn't have the time with the educator to understand the full picture, unfortunately."

Q5: Which competences do you think have been the most useful / are the most important to use in complex / sustainable design challenges?

R6: I discovered that understanding how things are connected (systems thinking) is important. Before the course I didn't know if and how municipalities and NGOs could collaborate and what roles I could have in this. I also discovered that acting and getting involved in the challenges is cool and giving.

I also didn't know my creativity could do a difference. But it can! I think the use of many of my competences are important. But communication and critical thinking is very important.

Q6: Did the DCT tool help you to understand how creative competences are related to sustainable competences?

R1: "It makes me feel better- I can do something good to the world – I found out I have so many nice skills!"

R2: "It guided me toward creating Something with bigger impact over just thinking basic on performance and doing "the right stuff."

R3: "It has created a deeper meaning and understanding of my way of working. I think I now have a different understanding of who I am and what I can do in a fucked-up world. It has helped to make me actually feel I can make a real difference with an important meaning for others as well. I had not at all guessed that my creativity had such a big impact on how I work and see my fellow students. It's been exciting."

Q7: How does working with the Sustainable Development Agenda in the DFC course make you feel?

R1: It "makes me feel like we are making an impact within the world. Like we are creating something with meaning."

R3: "At first very overwhelming to see the world has so many problems and so many people are suffering and lots of people don't care... then a feeling of empowerment and determination to help make a positive impact."

R2: "It is great motivation to create ideas that could change things ! Yet I feel demotivated by the feedbacks most of the time and settle down for more little projects..."

R4: "just fine to focus on the Sustainable Goals in an innovative process -, it puts a little perspective on how to develop an idea or product with a greater purpose. It was actually also a tough emotional process, I think."

But when making a survey amongst 33 fellow educators at VIA Design, only 32% of the educators found they had sufficient competencies to teach Educations for Sustainable Development. And this could also be one of the reasons why the students felt insecure to work in ESD's.

Research phase Three: educators survey results

The survey reveals that educator's competencies are not as developed but there is willingness to further develop/learn; there is a lack of confidence of the educators' own competences; presence of hesitancy towards adapting ESD, CE and CD into the curriculum as the educators experience a reluctant, slow and non-innovative industry. This portrays more of an attitudinal barrier were cultivating a sustainable mindset while enhancing CE and CD competencies might prove effective on a long-term.

Some of the practical challenges connected to teaching Sustainable Development or CE in Design Educations is of a generational origin. As some of the educators may have been educated in the 1980's, 90's or 2000's they are work within a linear production system and with a linear mindset and, as this research also shows, un-aware of new circular design-methods or principles. This makes it impossible to generate a systemic circular approach towards the fashion system. Alongside engagement in practice-based and action research, lifelong-learning for the educators is necessary to be able to understand the complexity, barriers, and opportunities that a circular fashion system. Furthermore, a transition for educators from an expert role to a facilitator can better manage exchange on circular information, enable a systemic approach and thus allow space for students to innovate. It is difficult to make the change happen as many of the present educators do not themselves have any experience or education with CE or CD in practice.

Discussion: Alone in the Wilderness, - The Educator and the Sustainable Competencies

When UNESCO puts education as the most regenerative potential of sustainable change, the potential is still restrained by the present practices of both management, educators and students when performing ESD. The "mirroring" of the present value-chains, linear extract driven exploitation of the Worlds resources and "growth" based business models brings us closer to the end of education as we know it today. UNESCO (2021) expresses great concern if we have reached the end of an educational practice and therefore need radical revisions of the practices.

In other words, there is a self-destructive culture immanent in the structures of academia and educational professions slowing the transition to the necessary ESD-status. As research on ESD stresses, the HE's need to initiate the changes rapidly and in holistic and systemic ways (Ives, Freeth & Fischer, 2019, Mulà et al. 2017). UNESCO defined a "whole-institution approach" which requires; (UNESCO, 2014)

1. An institution-wide process… that enables all stakeholders – leadership, teachers, learners, administration – to jointly develop a vision and plan to implement ESD in the whole institution.
2. Technical and, where possible and appropriate, financial support…to the institution to support its reorientation. This can include the provision of relevant good practice examples, training for leadership and administration, the development of guidelines, as well as associated research.
3. Existing relevant inter-institutional networks are mobilized and enhanced in order to facilitate mutual support such as peer-to-peer learning on a whole-institution approach, and to increase the visibility of the approach to promote it as a model for adaptation. (UNESCO, 2014)

But, as the need for a whole-institution approach is well documented, UNESCO has so far not yet expressed how it should be done in practice or implemented. In this regard the educator is still "alone in the Wilderness" – just like this study shows, applying and testing personal ideas, political beliefs, methods and transformative didactics. One of the major challenges is, that HE are sub-divided into faculties, institutes, disciplines of specialization. But – what if the HE's were divided into themes instead? This approach could include transdisciplinary project-based collaboration on issues like, inequality, welfare and health, water or new materials and thereby make research, epistemologies and practices dissolve into common exchanges of knowledge. Some HE's doing this in Denmark, i.e.; Roskilde University and Aalborg University, and the origins of the transdisciplinary, transformative ways of collaborating in Denmark often has an origin in the ideas and research made by Illeris, who has been an influential force in developing transformative learning theories. (Illeris, 2015 & 2014c).

In 2021 VIA University College, became a member of the UNESCO Associated Schools Program committing itself to a continuous development and support of working with the Sustainable Development Goals in a "whole-institution" approach. In this way the new importance of the educations, research, and activities of VIA points at the future of the students, projects, values, ethos, practices and beliefs of the future workforce, researchers, and educators – but the path is still practiced by repeating the present silos of research, education and value-chains in R&D and educational construction. The imperative to act differently has so far not emerged and reached the educators. We still practice what we did before. And the surrounding industries – as some of the input from the survey shows are reluctant if not hesitant to implement the needed changes and thereby the sustainable competences of the designers into their practice, which again makes the educators hesitant towards making radical alterations. Illeris (2014a) advocates for the implementation of transformative learning and project based (thematic) learning and demonstrates through his research how project studies differs from the tendencies towards competitive New Public Management based efficacy orientation on the educational institutional and political level. In many countries the efficiency of education is measured by and boosted through establishment of large institutions, exact learning objectives, testing and constant assessment of the objectives for students, staff and employees. Illeris points at the risk of developing "superficial" learning environments based on merely professional or academic syllabus rather than focusing on the students and educators transformative learning; personal development, tolerance, interaction with the surrounding world, deep understanding through action and flexibility. (Illeris, 2014a, p. 575)

At the Centre for Sustainable Fashion, at London College of Fashion, (LCF) UAL (Interim report 2016-19) Professor Dilys Williams, and Education for Sustainability Leader Nina Stevenson, have developed a "…framework and set of pedagogic principles have been developed to support evolutionary and transformatory approaches to fashion education, communicated through its research, teaching and learning and knowledge exchange projects. This includes the development of a framing of fashion education as a system, which has been applied to this plan". (Williams & Stevenson, 2018, p. 8)

The LCF approach is interesting in this connection as it is a full-scale attempt to implement both values, didactic and pedagogical principles, collaborations with the surrounding communities and forms the Education for Sustainability Transformation (EST) in Fashion strategy. It involves "long-term commitment to a transformational and evolutionary process of change that can take place inside and outside of formal teaching and learning, the university buildings, and disciplinary borders." (Ibid p. 8)

By setting a framework for EST The LCF sets new standards for both students and educators, collaborating companies and the surrounding society the understand the interconnectedness of personal beliefs, educational and research practices and their relevance to the connected industrial sector and society. (Rauch & Steiner, 2013) This could help the educators to feel together with someone in the Wilderness – and enable them to navigate through it together. (Wamsler, 2019)

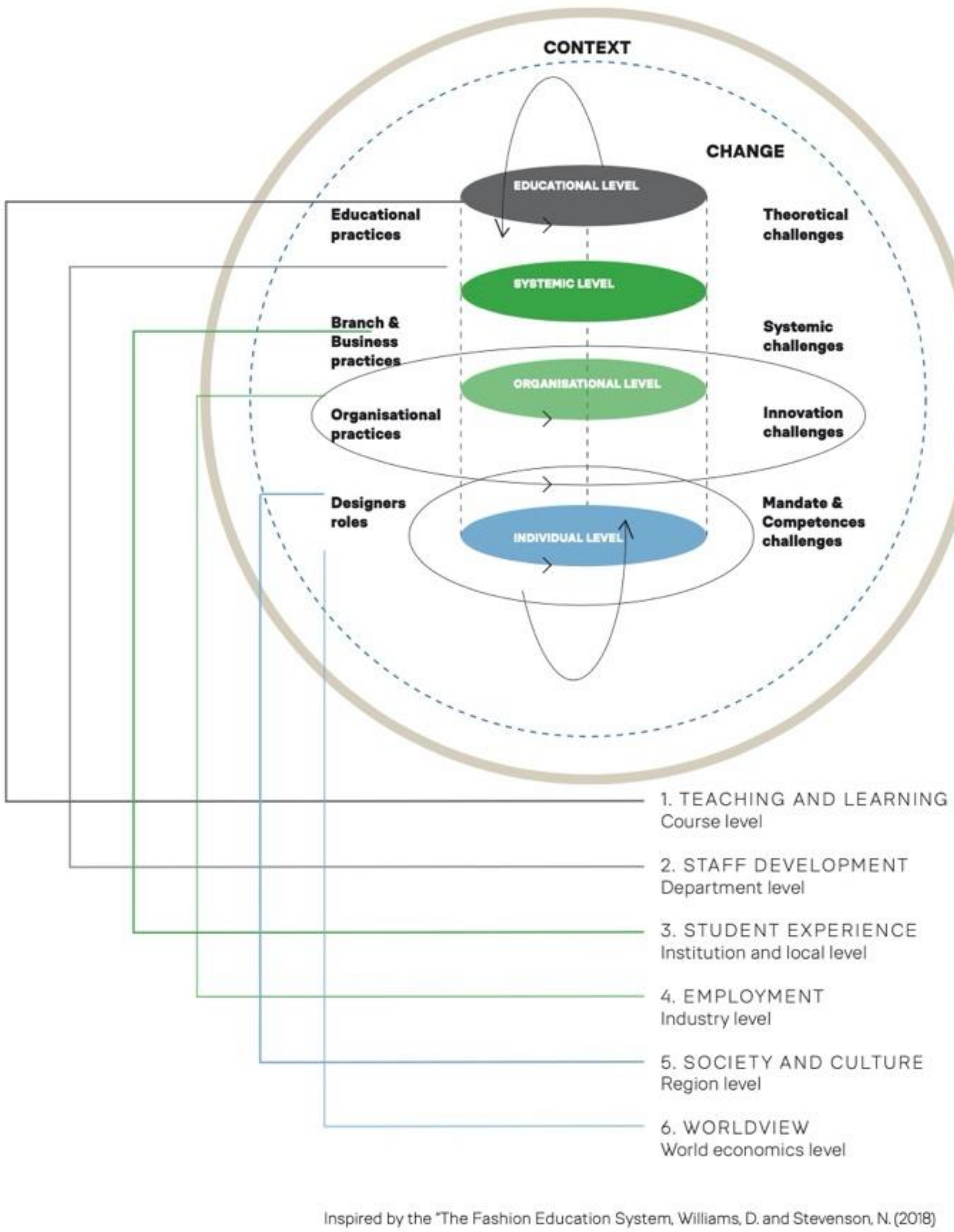


Figure 10: Illustration of the corelations between practice, roles and education adapted from Williams and Stevenson (2016).

The illustration is inspired from Williams and Stevenson, 2016, visualising how teaching and learning is highly connected to society and culture, staff development, industrial challenges, practices, organisational challenges and the expected and present roles of the designers in both education and employment. Education for Sustainability Transformation calls for a wider transdisciplinary approach which can help the educators to see inter-relations and common interests in developing new curricula. This could be done through themes – projects across silos. (Illeris, 2014c).

So, when two ESD researchers; Vare & Scott (2007) proposed using transformative learning didactics, based on dialogue to engage learners, they also demonstrated how this in turn can lead to sustainable change. But building the educators key competences necessary for sustainable development also requires the application of a transdisciplinary didactic approach. And as Kövesi et al., (2019) explains - adding new didactics to sustainable or CE-educations will challenge the educator even more. It requires a didactic framework in which all the implemented voices and views on the sustainable challenge can be heard, to avoid reluctance or hesitance towards integrating ESD principles to the education. Kövesi et al., 2019 stresses that educators are unlikely to feel "at ease" with teaching sustainable development issues if they are incapable of applying a didactic frame or understands the full picture themselves. Applying a transdisciplinary approach when developing pedagogical or didactic dispositions of ESD's can help enhancing the holistic professional understanding of sustainable complex challenges, but as Kövesi et al. experienced, the development of transdisciplinary teaching materials can be difficult and requires both time and a completely new way of working together across silos. And, as the survey shows, the educators are willing to make a change, but they are confused to what level they should start developing the alterations themselves or whether the management will help them. The change will also require a managerial mandate; time, economy and transdisciplinary courage when developing teaching materials, themes or didactic approaches together.

Perspectives:

This study has shown how the use of transformative learning methods; the DC-tool and Mezirows principles in the DFC course to a very large extent is in accordance with the latest recommendations of developing Educations for Sustainable Transformation. And by now, a huge variety of HE's have been working on and documented the implementation of ESD's. ESD - research shows many case studies of faculty or university specific transformation processes in changing curriculums and the efforts being made to enhance the student's competencies for Sustainable Development. But lately, research indicates promising opportunities when building and focusing on developing transdisciplinary ESD competencies among academic staff in HE's to provide change in curricula (Vare, 2018). In this way, facilitating "lifelong learning processes" amongst the academic staff can improve the overall ESD learning, interacting with the surroundings and teaching competencies, as well as this could even provide a new power of "meaningful reason" for management, educators, collaborating companies and in the end, the students. (Vare, 2018).

The educators somehow still feel they are "working alone in the wilderness", but the example from LCF with a clear vision, methodology and use of pedagogical transformative tools could enhance an Education for Sustainability Transformation. The LCF example is – in accordance with the principles of transformative learning and maybe we should elaborate on these ideas and apply project-oriented thematic ways of organizing the future design-educations. Also, more research on the field of Education for Sustainability Transformation Practices is needed as only little exists.

There is an anomaly between the wishes for the future of education from UNESCO and the real educational world which we need to address in research, practice, and learning. Educators are very often "alone" and needs research-based support to develop ESD's. The DECS project has provided insight in how educators can establish a new processual dialogue and transformative vocabulary between the students and the educator when working in ESD's and some improvements of the behavior and competence-development could be read from the first research made, using the DC-tool.

The real-life transformative learning setting of the DFC Course was determining the outcomes as the interaction with real people and companies was stressed again and again as important for understanding sustainable challenges as well as development in the student's reflections. The DECS project is a new useful reflection framework, for a progressive dialogue and informally extra-curricular based experiential learning. On the same level, the Rounder Sense Purpose Framework for evaluating the development of sustainable competences has been a very useful tool and has provided new insight. But both the Decoding Creativity Reflection Tool and the RSP tool are "extras" to the present curricula, and some students moaned about being forced to spend precious time on reflection-tools rather than working on their projects. And this calls for reflection from the educators.

References

Barth, M., & Rieckmann, M., (2012). Academic staff development as a catalyst for curriculum change towards education for sustainable development: an output perspective. Journal of Cleaner Production, 26(1), 28–36. DOI:10.1016/j.jclepro.2011.12.011

Barth, M., Godemann, J., Rieckmann, M., & Stoltenberg, U. (2007). Developing Key Competencies for Sustainable Development in Higher Education. International Journal of Sustainability in Higher Education, 8(4), 416–430.

B., Martinez-Villagrasa, Esparza, D. and Cortiñas, S. (2018). The Creative Competencies Dictionary, Between Design Practice and Education in 21st Century. Proceedings of the 20th International Conference on Engineering and Product Design Education (E&PDE18) September 2018.

Blaikie, N. (2003). Analyzing Quantitative Data. SAGE Publications Ltd. https://doi.org/10.4135/9781849208604

Dan, M. C., & Østergaard, T. (2021). Circular Fashion: The New Roles of Designers in Organizations Transitioning to a Circular Economy. The Design Journal, 1–21. https://doi.org/10.1080/14606925.2021.1936748

Friedman, Ken. 2019. Chatterjee Global Lecture. Design Education Today: Challenges, Opportunities, Failures. Cincinnati, Ohio: College of Design, Architecture, Art and Planning, the University of Cincinnati

Illeris, K. (2014c). Transformative learning re-defined: As changes in the elements of the identity. International Journal of Lifelong Education, 33, 573-586

Ives, C., Freeth, R. and Fischer, J. (2019), "Inside-out sustainability: the neglect of inner worlds", Ambio, pp. 1-10, available at: https://link.springer.com/article/10.1007/s13280-019-01187-w

Kövesi, K., Flament, S., Majou De La Debutrie, G., Sonntag, C., & Bluteau, H. (2019). Transdisciplinary approach to sustainable innovation and entrepreneurship education. Proceedings of the 46th SEFI Annual Conference 2018: Creativity, Innovation and Entrepreneurship for Engineering Education Excellence, 952–959

Lund, T. (2012). Combining Qualitative and Quantitative Approaches: Some Arguments for Mixed Methods Research. Scandinavian Journal of Educational Research, 56(2), 155–165. https://doi.org/10.1080/00313831.2011.568674

Mezirow, J. 2009. Transformative Learning in Practice: Insights from Community, Workplace, and Higher Education, Australia, Jossey-Bass.

Mulà, I., Tilbury, D., Ryan, A., Mader, M., Dlouhá, J., Mader, C., Benayas, J., Dlouhý, J., & Alba, D. (2017). Catalysing Change in Higher Education for Sustainable Development: A review of professional development initiatives for university educators. International Journal of Sustainability in Higher Education, 18(5), 798–820. https://doi.org/10.1108/IJSHE-03-2017-0043

Parodi, O. and Tamm, K. (2018), Personal Sustainability: Exploring the Far Side of Sustainable Development, Routledge Studies in Sustainability, Routledge, London.

Rauch, F., & R. Steiner. 2013. Competences for education for sustainable development in teacher education. CEPS Journal 3: 9–24.

Rieckmann, M. 2018. Chapter 2 - Learning to transform the world: key competencies in ESD. pp. 39-59. In: Leicht, A., J. Heiss, & W. J. Byun (eds.): Issues and trends in Education for Sustainable Development, Paris: UNESCO, http://unesdoc.unesco.org/images/0026/002614/261445E.pdf.

Ræbild, U., Riisberg, K., Hasling, M. (2019). The Benchmarking Report: Fashion SEEDS; Fashion Societal, Economic & Environmental Design-led Sustainability, Design for Planet - LAB for Sustainability and Design, Design School Kolding

Silverman, D. (2014). Interpreting qualitative data: David Silverman (Fifth edition). SAGE.

Sleurs, W. (2008). Competencies for ESD (Education for Sustainable Development) teachers: A framework to integrate ESD in the curriculum of teacher training institutes - Comenius 2.1 project 118277-CP-1-2004-BE-Comenius-C2.1.

Sterling, S. (2001). Sustainable Education: Re-visioning Learning and Change. Schumacher Briefings No. 6. Green Books Ltd.

Sterling, S. (2016). A Commentary on Education and Sustainable Development Goals, Journal of Education for Sustainable Development 10:2 (2016): 208–213

UNECE. United Nations Economic Commission for Europe (2012). Learning for the future: Competences in Education for Sustainable Development. Geneva: Unece.

UNESCO. (2021). International Comission on the Futures of Education: Progress Update. In Futures of Education, Learning to Become (Issue March). https://en.unesco.org/futuresofeducation/#s2

United Nations Educational, Scientific and Cultural Organization (UNESCO) (2017): Education for Sustainable Development Goals: Learning Objectives, Cross-cutting key competencies for achieving all SDGs, UNESCO 2017b, p. 10-55.

Wamsler, C, 2019, Education for sustainability. Fostering a more conscious society and transformation towards sustainability. International Journal of Sustainability in Higher Education Vol. 21 No. 1, 2020 pp. 112-130, Emerald Publishing Limited, 1467-6370, DOI 10.1108/IJSHE-04-2019-0152

Williams, D. and Stevenson, N. (2018), Context for Education for Sustainability Transformation, in UAL Interim report 2016-19, Education for Sustainability Transformation, London College of Fashion, 2018

Vare, P., & Scott, W. (2007). Learning for a Change: Exploring the relationship between education and sustainable development. Journal for Education for Sustainable Development, 1(2), 191–198.

Vare, P., (2018). A Rounder Sense of Purpose: developing and assessing competences for educators of sustainable development, Form@re - Open Journal per la formazione in rete, vol. 18, n. 2, pp. 164-173, Firenze University Press, DOI: http://dx.doi.org/10.13128/formare-23712 Firenze

Østergaard, T., (2018), ServDes.2018 Service Design Proof of Concept : Proceedings of the ServDes.2018 Conference. Meroni, A., Medina, A. M. O. & Villari, B. (red.). Linköping University Electronic Press, Linköpings universitet, s. 76-91 16 s. (Linköping Electronic Conference Proceedings; nr. 150).

Østergaard, T., (2019) Revising Creative Sustainability-competencies in Design Educations: The Future of Design, 1 nov. 2019, Decoding European Creative Skills: The Future of Design. Peña, J., Esparza, D., Clèries, L., Llàcer, T. & Martínez-Villagrasa, B. (Ed.) 1 Ed. Elisava, Barcelona. http://decoding.elisava.net/en/

Integrated studio approach to motivate collaboration in design projects

Virginie Tessier, University of Montreal, Canada

Abstract
In an attempt to resolve some of the gaps associated with the pedagogical integration of teamwork in design curricula, this article seeks to share a model for learning teamwork skills. This model is the result of a multiple case study methodology based on the learning experiences of 22 design students. Data was collected during various team projects through questionnaires and interviews. In relation to the concept of the zone of proximal development, the coded data was organised by thematic categories and training levels to provide a practical tool to support teaching and assessment practices to encourage the learning of teamwork skills. The proposed model allows for a systemic understanding of teamwork skills that should be acquired during design training to navigate with efficiency and confidence in the collective projects of design's community of practice. The use of the model promotes the adoption of more complex teamwork dynamics, such as collaboration, enhanced with an integrated pedagogical approach. It also motivates individual action towards collaborative initiatives in the hopes of more coherent teamwork processes.

Keywords:
Design, teamwork, collaboration, process, project-based learning, zone of proximal development

Introduction
Since the 1980s to the mid-1990s, the design community has recognised and valued the social dimension of its processes. For example, Bucciarelli (1988) positioned design as a social practice, Cross and Cross (1995) studied the distinctions between different team processes, and Goldschmidt (1995) compared individual and collective practices. Since then, design has been more and more leaning towards shared and collective processes. As Goldschmidt (1995) stated, the complexity of design projects led designers to be confronted with 'the need for multiple expertise and division of labour' (p. 189). Nevertheless, an integrated vision of the project is crucial to support complexity and encourage its deep understanding by project experts (Stompff & Smulders, 2013). Accordingly, the application of pre-existing solutions is neither possible nor desirable.

The last decade and the most recent international crises have confirmed the need for practitioners to develop new skills to conduct their tasks and projects in complex circumstances. Above all, understanding and optimising the work that is carried out in partnership with others is fundamental to propose innovative solutions created from new knowledge (Minder & Lassen, 2018). In that context, professional designers have been invited to join projects initiated by many disciplines, ranging from medical products, ergonomic solutions, technological innovations, marketing initiatives, etc. In that sense, the designer has become a generalist that masters a creative process and analytical skills to converge to meaningful and innovative propositions.

Building on these insights from practice, teamwork is now an accepted way of working in design. The industry and design agencies are explicitly asking for teamwork skills from novices as they integrate their work environments (Sands & Worthington, 2007; Council for Interior Design, 2020). Unfortunately, knowledge on that matter can be difficult to gain because of the multiplicity of factors that differentiate these experiences. Most of our past research initiatives have been directed towards gaining a better understanding of these collective dynamics of design activities (Zahedi et al., 2017, 2018; Tessier & Zahedi, 2019). However, the integration of teamwork within design curricula around the world does not seem to have been the subject of consistent inquiry to ensure the coherence of its teaching, learning methods, and assessment practices. Despite the repeated efforts of teachers and institutions to offer learning situations that are based on authentic practices, most tend to assume that teamwork skills are "learned 'on the job'" (Kleinsmann et al., 2012, p. 502), resulting in limited training for this set of skills.

From our experience in design education and research, we notice that teachers are proposing team projects as part of their classes or workshops, but most often without reflecting on the necessary skill set to gain performance for team projects or the optimal learning progression to achieve such performance. Among others, Tucker et al. (2014) and Kleinsmann et al. (2012) did start to draft typologies distributing teamwork experiences across typical design curricula. Still, the lack of attention offered to learning methods and assessment practices to judge the performance of students or teams does not encourage the optimal integration of these frameworks within the pedagogical environment (Davies, 2016).

This paper will explore the actual situation of teamwork skills development in design programs. To better understand how students learn teamwork, we will trace how they experience these learning situations to propose a potential framework and orient its pedagogical alignment. In hopes of proposing paths for meaningful solutions to the identified gaps, we will first introduce teamwork by defining some of its main concepts, presenting a selection of benefits for design practice, and exposing the recurring educational challenges that structure our inquiry. Next, we will present our multiple case study methodology based on the team projects of 22 undergraduate students. These case studies will allow us to gain an in-depth understanding of how students live their workshop experiences when projects are conducted in teams. The following part of the article will share the qualitative data analysis process and create links with the theoretical concept of the zone of proximal development, which understands learning as continuously ongoing and collectively influenced. Such an interpretation will allow us to propose a model to facilitate complex teamwork skills integration during design training. To conclude, we will discuss the proposed model, its implications for design education and elaborate on the preparation of novices to navigate with confidence in the collective projects of design's community of practice.

Defining team dynamics

Based on a recently published scoping review on the subject (Tessier, 2020, 2021), we identify three main team dynamics that are solicited in design practice: coordination, cooperation, and collaboration. These dynamics all ask for the contribution of multiple individuals but are also differentiated based on distinctive characteristics.

First, coordination is noted when parts of a project are segmented and organised sequentially. Bedwell et al. (2012), Burkhardt et al. (2009), and Kvan (2000) explain coordination in relation to strategic planning, division, and sequential organisation of tasks. Project assignments are divided between team members, who work in isolation, according to their skills or interests.

Secondly, cooperation builds on shared objectives combined with simultaneous task distribution. "Reciprocal interaction" defines this dynamic (Bedwell et al., 2012, p. 136), as the contributions of team members enrich and contribute to one another. According to Achten (2002), "in cooperative design, participants get such parts to solve and later integrate in partial solution that are integrated in a whole design" (p. 4). In that context, good communication is necessary to ensure cohesion of efforts.

Thirdly, collaboration translates into a complex team dynamic, asking for high interdependence, shared comprehension, and the definition of common objectives (Chiocchio et al., 2011; Kleinsmann, 2006; Kvan, 2000). Kleinsmann (2006) defined collaboration as a process built from a series of stages based on knowledge sharing. During collaboration, most tasks are accomplished as a team, resulting in an integrated and shared result.

These short descriptions indicate various levels of team cohesion. Accordingly, coordination asks for limited cohesion, cooperation demands moderate cohesion, while collaboration needs optimal cohesion. Team dynamics contribute to structuring teamwork in different ways and for different purposes. Some team dynamics are more complex than others, which makes it important to expose students to different types of situations and favour different levels of teamwork through their pedagogical experiences. On one hand, if the most complex dynamic is introduced too soon in the learning process of students, they risk to not be equipped to perform as it is too complex. On the other hand, if projects are not planned in order of complexity, students will not acquire relevant and varied teamwork experiences. The distinctions between team dynamics are important as different kinds of situations call for different types of teamwork. The next section will introduce some of the reasons why teamwork is crucial in the training of future designers, and why the most complex form of teamwork (collaboration) should be practised by design students.

Benefits and challenges of learning teamwork skills

Teamwork opportunities present a series of benefits that are important for the training of novice designers. Among other things, teamwork allows creating links and associations of ideas between fields of knowledge as a whole (Boud & Falchikov, 2006; Carroll et al., 2014). Keeping students active, team projects contribute to student motivation, autonomy, transversal skills development, and deeper learning (Blumenfeld et al., 1991; Davies, 1996; Oxford, 1997; Shepard, 2000; Helle et al., 2006; Scallon, 2007). When facilitative, teamwork encourages a less timely project process, while also allowing dealing with more complex issues (Stempfle & Badke-Schaub, 2002; Kleinsmann et al., 2007). When regressive, teamwork can lead to improper decisions, unsuccessful organisation, limited knowledge sharing, and the initiation of a stressful environment (Tessier, 2021).

The lack of structured approaches to implement teamwork within design curricula results in recurring challenges that are reported by students, teachers, and researchers. One recurrent challenge touches on the difficulty to bring students to collaborate, as it is a complex dynamic to put together. Previous studies have noted that most students tend to work in teams according to less complex dynamics, such as cooperation or coordination, by distributing tasks and limiting exchanges (Davies, 2016; Zahedi & Heaton, 2017). This tendency has also been noted in the professional world where Stompff and Smulders (2013) have observed that recurrent division of labour within teams leads to a lack of global vision resulting in fragmented solutions. However, although collaboration might ask for increased efforts from team members, important benefits should result in higher quality projects (Tucker & Reynolds, 2006). Such benefits should be explicitly communicated to students, so they can consider the added value for their project. Otherwise, they might not understand why it is worth investing the time and the efforts. An important challenge to overcome is, therefore, the explicit integration of collaborative experiences into the workshop formation of design students. This objective seeks increased social relevance by contributing to a student's success and motivation while preparing novices to the reality of their professional practice. The next section will expose the details of the methodology that was organised to gain clearer insights about the reality of workshop team projects.

Multiple case study methodology

Wishing to gain a deeper understanding of the learning experiences of undergraduate students during their team projects, a multiple case study methodology was put together to access a complementary pool of experiences. Twenty-two undergraduate students were recruited to participate in the research from various design programs offered at the Faculty of environmental design of the University of Montreal (Canada; industrial design, interior design, urban design). The participants were accepted in the research if they were working as a team on a workshop project during the period of data collection. For ethical reasons, all participation was determined on an individual basis (which sometimes resulted in having only one team member to comply with the research). Still, the participants of Group E worked in pairs and all teammates accepted to join the research. According to the pedagogical project, data collection varied between five to seven consecutive weeks. Participants were of various training levels and in strategically different learning situations to provide a scope of experiences. All participants were engaged in a team workshop project specific to their educational program and received instructions for their projects from their workshop tutor (their participation in the data collection was non-mandatory and considered additional to their pedagogical training). The research tried to work the design projects without disrupting the unfolding of the workshops. The project topics were varied and whether the team was marked for teamwork or not was left to the discretion of the workshop tutor. The contextual information shared in Figure 1 is organised according to five distinct groups that will help us later to differentiate the results according to the training levels of the participating students.

	Group A	Group B	Group C	Group D	Group E
Discipline	Interior design	Urban design	Industrial design	Interior design	Industrial design
Age range	18-23	20-40	22-24	35-36	22-33
Training year	First year	Third year (final)	Third year (final)	Fourth year (final)	Fourth year (final)
Type of teamwork	Disciplinary	Disciplinary	Interdisciplinary	Interdisciplinary	Disciplinary
Number of participants	4	4	4	2	8
Data collection *(Length in weeks)*	6 weeks	7 weeks	5 weeks	5 weeks	6 weeks
Project topic	Redesign of a school library	Planning of a vacant lot	Design of opera costumes	Design of opera sets	Varied thematic projects

Figure 1. Portrait of participants

All participants were asked to fill weekly questionnaires organised around 3 questions:

- What is your project and how has it evolved this week?
- What were your team's challenges and how could they be solved?
- How were your team's decisions taken?

The questionnaires were designed to take less than 20 minutes to fill to encourage students to participate in the research. They offered information about the present events of the participating students. The content of the questionnaire was explained in more detail as part of a past publication (Tessier & Zahedi, 2019).

The questionnaires were combined with a one-to-one interview at the end of the workshop projects. These interviews provided clarifications on the reported experiences described by the participants. They allowed the researcher to dig deeper into the challenges reported by the student and to gain a more accurate comprehension. Most of all, the interviews contributed to the understanding of the participant's vision of his or her experience. Interview questions were organised to bring the participant to gain perspective on his experience, develop its reflectivity regarding his team's situation, and propose alternative ways to overcome or address his team's recurring challenges in the future.

This multiple case study methodology resulted in a mass of data from which sense needed to be made by finding patterns and creating meaning through data analysis, which is described next.

Data analysis

All data from the questionnaires and the interview verbatim were transcribed in the coding software MAXQDA. A coding process was motivated to gain a sense of the data based on the stories and experiences of multiple individuals. An open coding strategy allowed us to create links and compare the different groups by converging from "raw data to a standardised form" (Babbie, 2008, p. 355). Coding was focused on the lived experience of each participant and the influencing factors of teamwork. Codes were not defined in advance but emerged according to our interpretation of the data. The coding process started from Group A to Group E and was refined through multiple readings of the verbatim transcriptions. A total of 97 codes emerged from the coding process. Cross-verification and code organisation allowed us to combine or delete some of these codes, resulting in 33 codes describing the teamwork experiences of the 22 participants. Moreover, all codes were organised into five categories (zones), corresponding to thematic groups around a shared topic:

- Personal zone: Refers to features and motivations of team members
- Project zone: Refers to factors that facilitate or complicate the project
- Organisational zone: Refers to team management, division, and prioritisation
- Learning zone: Refers to new knowledge or skills developed in line with the project
- Social zone: Refers to the emerging relations between individuals through interactions

The codes as categorised in the five zones were interpreted as characteristics of teamwork learning experiences. All characteristics were analysed across the set of data, which allowed the identification of 81 analysis factors (see Appendix), increasing our specific understanding of the data. These factors emerged from the code analysis by looking for patterns to gain a deeper understanding of the various dimensions of each characteristic. In other words, the factors were identified as part of the analysis of each specific code by trying to differentiate the ways that were put in action by the participants. This process led to a clearer categorisation of the new information. Unfortunately, the scope of this article does not allow us to provide more details of the descriptive factors. Still, a good example would be according to characteristic 2.2 – Expressing ideas that is associated with three factors: (a) Proposing ideas individually, (b) Combining ideas, (c) Fixation (see this characteristic in the Appendix). These factors provide alternative stages in a team's effort to communicate possible insights according to a person's effort, a team's contribution or not being able to do either of these possibilities. Factor A was identified in all groups, Factor B only in some of them (Groups A, C, and E), and Factor C, only in group E. These distinctions across groups of students show that not all students did achieve to combine their ideas as part of their teamwork experience. Moreover, investigating deeper into group E's difficulties translates the high complexity of their projects, resulting in a decline of some students' abilities to generate ideas.

Such an analysis was carried for every characteristic, shedding light on the similarities and distinctions between each group. The analysis also guided the identification of the characteristics and factors that were predominant in the teamwork experiences of each group. Also, it underlined in particular which challenges were considered optimal for learning or too difficult concerning a certain learning context (for ex.: level of training or disciplinary/interdisciplinary). Such distinctions motivated the connection with the theoretical concept of the zone of proximal development, which is explained next.

Zone of proximal development

The zone of proximal development is a fundamental concept of the sociocultural perspective, which was introduced by Vygotsky (1978). Through his study of children's development, Vygotsky came to understand cognitive growth as a continuous process according to which present abilities offer clues of one's future capacities.

The zone of proximal development is often illustrated as proposed in Figure 2. This representation shows the various stages that a learner encounters as part of his learning process. Still, the zone of proximal development is not entirely based on the sole learner but is also influenced by external support being provided to the learner as he develops more autonomy. Therefore, as shown in Figure 2, the central part of the model (Zone A) indicates all abilities that are mastered by an individual and that can be accomplished autonomously. The next section of the model (Zone B) translates what the learner can do with the help of a peer, teacher, or adult (often said to be a more capable peer). Finally, the external zone of the model (Zone C) identifies what the learner is not able to do either alone or with external help.

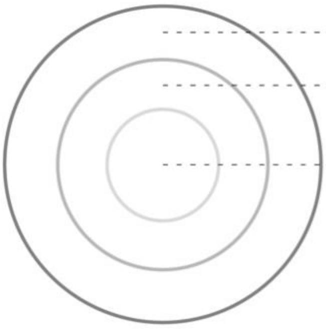


Figure 2. Zone of proximal development

As part of the described learning process, social interactions are crucial for the learner to progress across the zones. Travelling in the model translates into a cyclic process as the learner gains more autonomy for certain abilities, tasks, or knowledge. This program enables the learner to access more complex fields of knowledge, for which he or she needs external support. As part of this research, the concept of the zone of proximal development was judged highly relevant to help in the organisation of the collected data since it is primarily based on social interactions, which is also the basis of teamwork. Accordingly, the concept of the zone of proximal development is interested in socially constructed knowledge. Also, the concept was found particularly interesting as it allows a multi-level analysis. The levels allow a systemic understanding of the studied situation by considering all of its active components: the independent actions, the collective activities, and the socio-cultural context, which are relevant for the study of complex activities, such as teamwork.

Zone of proximal development for teamwork skills model

The interactions that emerged between the data collected, the analytical interpretation, and our comprehension of the zone of proximal development guided the development of an integrative model. The factor differentiation allowed to distil and categorise the characteristics and factors according to different stages. Figure 3 identifies the classification of the characteristics and factors shared in the Appendix of this paper into the 'zone of proximal development for learning teamwork skills' model. Characteristics were classified into the model according to their importance in the discourse of each group of participants. As a matter of fact, some characteristics or factors are specific to a stage in the model (when identified at a specific level), while others are transversal (when identified outside of the model, near the zone title). Two zones of the model were left blank since no specific characteristic allowed to differentiate this level from the others.

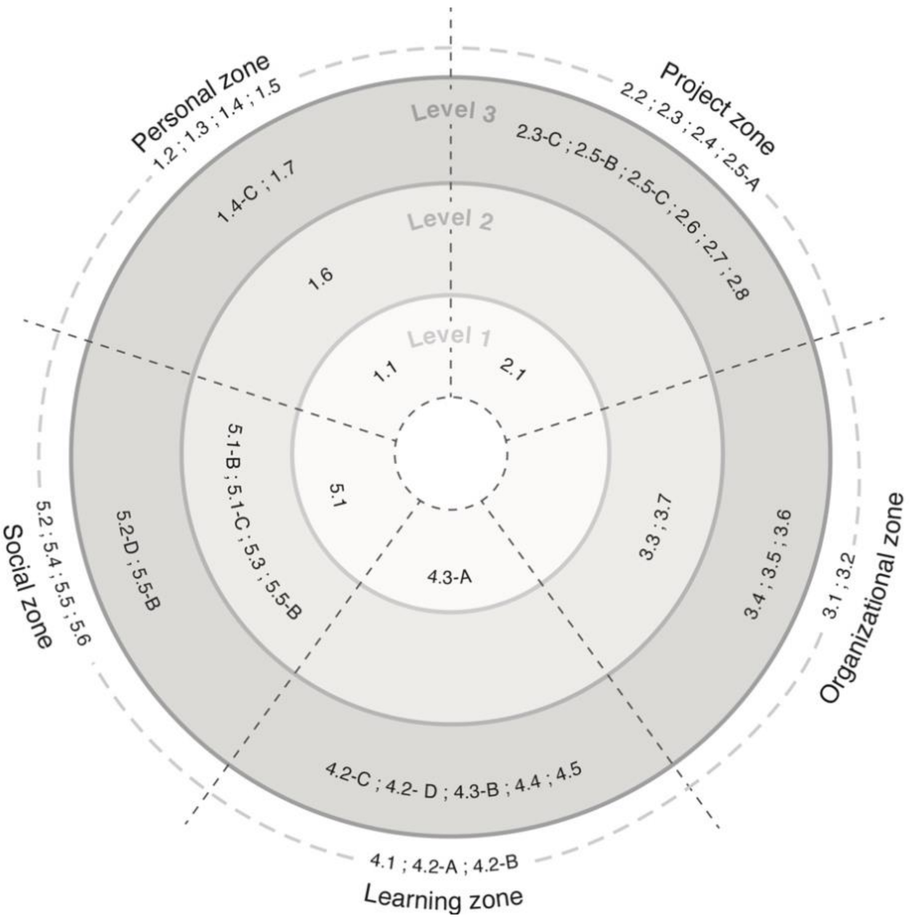


Figure 3. Distribution of the characteristics and factors in the model (all codes are associated with the Table in the Appendix)

The following Figure 4 is a synthetic interpretation of the ‘zone of proximal development for learning teamwork skills’ model shared in Figure 3, which is strongly inspired by the initial zone of proximal development model. First, it shares the same circular shape divided into increasingly complex levels. Secondly, the levels of complexity also imply that skills from a previous level need to be mastered before being able to perform correctly in the next level. Thirdly, the learner’s development is supported and encouraged by external peers such as teammates, workshop tutors, and others. Group learning directly contributes to the development of teamwork skills.

Still, some differences are noted. First, it is divided according to the five categories that emerged from our analysis process, creating zones of skills to master. Secondly, it is composed of four different circular levels. The core of the model represents the prerequisites that are requested by academic institutions. The next circle is concerned with first-year students (Level 1), integrating a new environment based on high standards. As part of the personal zone, the participants corresponding to this stage showed they needed adaptative skills to adjust to the requirements of their undergraduate program. Similarly, the other zones also translate the need to acquire disciplinary-specific tools and skills to ensure a good progression throughout the following stages. Therefore, the project zone is set to understand and master the design process and the organisational zone seeks the development of organisational skills to facilitate task division among team members. The learning zone is specific to mastering some of the basic tools of the designer such as drawing or using software. Finally, the social zone asks to work on communicative skills, so students can share time with other individuals, recognise each other's forces and manage conflicts. These characteristics associated to level 1 were mostly identified in Group A, which was starting its second year of study during the process of data collection.

Figure 4. Zone of proximal development for learning teamwork skills model

The next circle is related to second- or third-year design students (depending on the curriculum; Level 2). A different set of skills are identified in continuation with what was acquired in the previous level. Interpersonal relations tend to grow into friendship as students get to know each other: therefore, the personal zone seeks concentration to stay focus and not be disturbed by workshop stimuli. Next, the project zone is associated with students' initiatives to navigate more fluidly in the design process, take action and propose frame structuration. The organisational zone is concerned about efficiency to gain autonomy to formulate and accomplish tasks. The learning zone is related to skill development as a global improvement of disciplinary-specific and generic abilities. Lastly, the social zone corresponds to the development of the capacity to defend an opinion or a position. As communication and relational skills should be practised during various project experiences, one also has to be able to build its own perspective.

The last level (Level 3), which leans towards the professional world, corresponds to third- or fourth-year design students (last year of an undergraduate program). These students should be transitioning towards their future community of practice as they acquire a certain skill set in interaction with professionals. The personal and social zones seek similar objectives in the construction of the professional identity of the student: affirmation of self and building an argument. The project and the learning zones both translate the authenticity of the proposed learning situations, the increased complexity of the project, and the feasibility of the proposed solution. The organisational zone seeks to facilitate prioritisation during projects to meet the deadlines, comply with constraints, propose a realistic timeline, etc.

Overall, each level of the model corresponds to a specific range of training years but achieves coherence throughout a curriculum by progressing from an individual perspective through a more complex collaborative attitude. As proposed by the zone of proximal development, external social support is fundamental to skill development. As stages are crossed by the students, it was noted that more actors join in the process to contribute to the project with their specific expertise. In the first level, it is mostly the teacher that contributes as external help to the team project. At the second level, the peers or class colleagues are solicited for advice on ideas or the project. Finally, the third level seeks more complex design projects and asks for the input of professionals or potential users according to specific domains of expertise to complement students' knowledge. Lastly, the dashed zone outside the model represents the transition with professional practice. As learners finish their studies, it is crucial to favour mutual exchange between students and experts to enrich their formation by introducing them to the basics of practice. Before concluding the paper, the next section will discuss the pedagogical potential of the model to favour collaborative dynamics in studio projects.

Pedagogical potential of the model

The "zone of proximal development for learning teamwork skills model" offers more than a picture of the stages that many design students go through during their formation. As it is well known, many design programs are built on very similar Bauhaus-inspired project-based structures, supporting the significance of this research's contribution. The model underlines the importance of acquiring strong disciplinary bases to support the development of skills and autonomy across the various zones of the pedagogical experience and for lifelong learning through professional practice. In summary, the first zone is focused on understanding the design process, which is crucial to master different types of tools, methods, and idea generation techniques. The second zone is concerned about developing social relations and developing the previously acquired skills and the third zone values the integration in the community of practice with direct interactions with experts, internships, or external guest jurors. For the present discussion, we will tackle three potential benefits of the model if integrated in design education: a framework for pedagogical alignment, a perspective to develop reflectively and proactively, and a tool to motivate more complex collaborative dynamics.

A framework for pedagogical alignment

Biggs (1996) raised the importance of planning a constructively aligned curriculum to provide a coherent structure to the learning process and increase students' investment in diverse categories of knowledge. Constructive alignment seeks to implement a structure between teaching, learning, and assessment practices of a class or workshop, but also, more globally, throughout the educational strategies and learning experiences of a curriculum. Such coherence supports deeper learning and a better understanding of the aimed objectives.

In that sense, our model for learning teamwork skills offers a clear structure and sequence to develop the autonomy of students for teamwork dynamics. The model proposes a progression from individual actions to collaborative initiatives by using the design project as its main motivation, guiding students from the centre of the model to its periphery. In that sense, the learner gains autonomy to accomplish teamwork in more complex contexts as he or she progresses in the model.

The proposed model can be used to prepare teaching activities according to students' training level and to assess learning according to each characteristic's factors and whether the learner is lower or above the attended level. Moreover, the model can also be presented and explained to the students for them to take part in the judgement of their performance. By using the model as a reference point among pedagogical actors, teachers, learners or their teams can pinpoint the zone(s) where they feel less confident and envision where they should be aiming. By understanding the global picture, design students would be empowered to reflect more deeply on their abilities and skills.

A perspective to develop reflectively and proactively

The proposed model, based on the zone of proximal development, also supports the development of a reflective practice by perceiving the global picture and allowing further discussions between the actors involved. During the interviews of our data collection, the participants were invited to discuss further the challenges they faced. The researcher tried to create a dialogue to deepen the reflective perspective of the participant on its own experience. When successful, the participant was able to propose concrete ways to improve their attitude, take actions or strengthen their team relationship and interactions. The capacity to find solutions based on their interpretation of the situation can demonstrate an active cognitive process and a desire for change. As Argyris and Schön (1977) demonstrated, professionals work according to their tacit knowledge, indicating that a large part of knowledge unfolds through imitation, observation, and interaction.

Proactively, the observations that students make on themselves allow for sustained mediation by and for the students in relation to their practices and needs. The student can compare his behaviours with himself or with his colleagues in terms of his progress, skills, and challenges. In our proposal, feedback is constructive since it brings new knowledge to the student while being framed by a structure motivating collaborative design. Therefore, it is possible to see how the model for learning teamwork skills could support the analysis of one's actions and behaviours, resulting in a more autonomous, constructive, and reflective practice. Offering common reference points to initiate conversation, the model should lead to a more thoughtful practice in the hopes of developing reflective habits and promoting collective behaviours in the attitudes of future professionals.

A tool to motivate more complex collaborative dynamics

Students generally choose to distribute work to focus their efforts on the tasks at which they already excel, limiting their interactions to the minimum. This mindset promotes time and task efficiency over a more integrated project process and the development of new skills. As mentioned by Tessier (2020), coordination, cooperation, and collaboration can be organised according to their level of cohesion. These levels were confirmed in the data we collected, as similarities were identified according to the levels of cohesion and the stages of the model. For example, coordination was identified predominantly in the behaviours of participants associated with level 1, cooperation to participants of level 2, and collaboration to participants of level 3. Still, we confirm the limited presence of collaboration, except for teams that conducted complex projects. This tendency was also observed by Zahedi (2019). Only the participants of Group E, which were the most advanced in their formation, showed the most collaborative behaviour by working together, building shared comprehension, using boundary objects, negotiating through their complementary forces, and sharing common objectives.

This limited presence highlights the necessity to favour an explicit pedagogical strategy for implementing more complex team dynamics into design training. As students progress in their formation, they should be exposed to varied dynamics to build a complementary repertoire of experiences. As we observed with the analysis of the multiple case studies, the lack of explicit training on team dynamics slows down the adoption of more complex team dynamics and diminishes the potential benefits that teams could implement in their projects. On the one hand, task complexity encourages the adoption of collaborative behaviours as efforts have to be combined to propose a valuable solution in line with its initial context. On the other hand, too much complexity blocks team members and promotes less complex dynamics (such as coordination or cooperation). The social scope of design should be considered as a whole, as soon as the first-year students integrate their design program to introduce such disciplinary values into their mindset. Despite the levels of cohesion between team dynamics, teams are guided by the centrality of the object in the project process. As mentioned by Geisler and Rogers (2000), the object to be produced is what directs and coordinates the project's efforts.

Conclusion

In conclusion, educational institutions should concentrate on renewing their practices and developing their strategies to ensure that novices are ready and confident to perform in professional projects. Greater awareness to the pedagogical expression of teamwork skills would allow constructive alignment throughout the educational experience. Still, full pedagogical coherence can only be achieved when all principles are applied as an integrated program approach (which might be difficult to implement in the short term).

This brings us to identify some of the limits of the framework presented in this paper. First of all, the proposed model is based on limited data. Although we were faced with an important mass of verbal and written data from our participants because of the longitudinal scope of the data collection strategy – only 22 students were enrolled in the study. In that sense, the study is exploratory as it allowed to investigate broadly a new context. Secondly, participating students were part of the same context of study (i.e. all enrolled at the same university). Efforts were made to recruit students from various programs and training levels, but since they are all from the same teaching institution, chances are high that they share very similar philosophies and visions. Finally, a last limit is also due to the exploratory nature of the study: there has been no real-life implementation of the proposed model. Of course, we hope to be able to share future research reflecting on our attempts to implement the framework as part of various workshop team projects or as a program approach. In the future, we wish to study more varied learning contexts and apply the recommendations that were discussed in this article.

In conclusion, this article shared a research initiative that sought to understand teamwork experiences as design students live them. The analysis of qualitative data collected from 22 participants of various design programs and levels supported the development of a model based on the concept of the zone of proximal development. This model, which is shared as the main contribution of this article, gathers 33 characteristics of teamwork design projects distributed in 5 zones (personal, project, organisational, learning, and social). These zones are subdivided into three levels corresponding to introductive, mid-, and advanced levels. The model can be used in support of all three fundamental activities of educational practice by facilitating teaching and pedagogical tasks, supporting learning, and offering guidelines for self-assessment or co-assessment. Seeking for more coherence within the pedagogical strategies of a training program can only be more positive for the learners by bringing them to see the global picture, understand the need for complex team dynamics, and offer clear stages to reach mastery of design as a social practice. Using the project as its main motivation, the model works around complementary skills to achieve teamwork coherence, as designers often take on the fundamental role of group facilitators in the projects in which they participate (Kleinsmann et al., 2012).

Acknowledgements

The work shared in this paper is part of the author's Ph.D. thesis (Tessier, 2021). Many thanks to Prof. Mithra Zahedi, Prof. Isabelle Nizet, Prof. Anne Marchand, Prof. Rabah Bousbaci, and to all the participants of this study. This work was funded by the Fonds de Recherche du Québec – Société et Culture (no. 256855).

References

Achten, H. (2002). Requirements for collaborative design in architecture. Design & Decision Support Systems in Architecture, Avegoor, The Netherlands. http://papers.cumincad.org/cgi-bin/works/Show?ddssar0201

Argyris, C., & Schön, D. A. (1977). Theory in practice: Increasing professional effectiveness (First Edition). Jossey-Bass.

Babbie, E. (2008). The Basics of social research (4th edition). Thomson Wadsworth.

Bedwell, W. L., Wildman, J. L., DiazGranados, D., Salazar, M., Kramer, W. S., & Salas, E. (2012). Collaboration at work: An integrative multilevel conceptualization. Human Resource Management Review, 22(2), 128–145. https://doi.org/10.1016/j.hrmr.2011.11.007

Biggs, J. (1996). Enhancing teaching through constructive alignment. Higher Education, 32(3), 347–364. https://doi.org/10.1007/BF00138871

Blumenfeld, P. C., Soloway, E., Marx, R. W., Krajcik, J. S., Guzdial, M., & Palincsar, A. (1991). Motivating project-based learning: sustaining the doing, supporting the learning. Educational Psychologist, 26(3–4), 369–398. https://doi.org/10.1080/00461520.1991.9653139

Boud, D., & Falchikov, N. (2006). Aligning assessment with long-term learning. Assessment and Evaluation in Higher Education, 31(4), 399–413. https://doi.org/10.1080/02602930600679050

Bucciarelli, L. L. (1988). An ethnographic perspective on engineering design. Design Studies, 9(3), 159–168. https://doi.org/10.1016/0142-694X(88)90045-2

Burkhardt, J.-M., Détienne, F., Hébert, A.-M., Perron, L., Safin, S., & Leclerq, P. (2009). An approach to assess the quality of collaboration in technology-mediated design situations. Designing beyond the product - Understanding activity and user experience in ubiquitous environments. European Conference on Cognitive Ergonomics, Helsinki, Finland. https://dl.acm.org/doi/10.5555/1690508.1690551

Carroll, J. M., Jiang, H., & Borge, M. (2014). Distributed collaborative homework activities in a problem-based usability engineering course. Educ Inf Technol, 20(3), 589–617. https://doi.org/10.1007/s10639-013-9304-6

Chiocchio, F., Forgues, D., Paradis, D., & Iordanova, I. (2011). Teamwork in integrated design projects: Understanding the effects of trust, conflict, and collaboration on Performance. Project Management Journal, 42(6), 78–91. https://doi.org/10.1002/pmj.20268

Council for Interior Design Accreditation Professional Standards (Ed.). (2020). Professional standards 2020. Council for Interior Design Accreditation. http://accredit-id.org/professional-standards/

Cross, N., & Cross, A. C. (1995). Observations of teamwork and social processes in design. Design Studies, 16(2), 143–170. https://doi.org/10.1016/0142-694X(94)00007-Z

Davies, A. (1996). Assessment and transferable skills in art and design. International Journal of Art and Design Education, 3, 327–331. https://doi.org/10.1111/j.1468-5949.1996.tb00007.x

Davies, M. (2016). “Normal science” and the changing practices of design and design education. Visible Language, 50, 6-23.

Davies, M. (2016). “Normal science” and the changing practices of design and design education. Visible Language, 50, 6–23.

Geisler, C., & Rogers, E. H. (2000). Technological mediation for design collaboration. ACM International Conference on Computer Documentation, 395–405. https://doi.org/10.1109/IPCC.2000.887297

Goldschmidt, G. (1995). The designer as a team of one. Design Studies, 16(2), 189–209. https://doi.org/10.1016/0142-694X(94)00009-3

Helle, L., Tynjälä, P., & Olkinuora, E. (2006). Project-based learning in post-secondary education: Theory, practice and rubber sling shots. Higher Education, 51(2), 287–314. https://doi.org/10.1007/s10734-004-6386-5

Kleinsmann, M. (2006). Understanding collaborative design [Ph.D.]. Delft University of Technology. https://repository.tudelft.nl/islandora/object/uuid%3A0a7a57d4-c846-4458-a59f-24c25acbafa9

Kleinsmann, M., Deken, F., Dong, A., & Lauche, K. (2012). Development of design collaboration skills. Journal of Engineering Design, 23(7), 485–506. https://doi.org/10.1080/09544828.2011.619499

Kleinsmann, M., Valkenburg, R., & Buijs, J. (2007). Why do(n’t) actors in collaborative design understand each other? An empirical study towards a better understanding of collaborative design. CoDesign, 3(1), 59–73. https://doi.org/10.1080/15710880601170875

Kvan, T. (2000). Collaborative design: What is it? Automation in Construction, 9(4), 409–415. https://doi.org/10.1016/S0926-5805(99)00025-4

Minder, B., & Lassen, A. H. (2018). The Designer as Facilitator of Multidisciplinary Innovation Projects. The Design Journal, 21(6), 789-811. https://doi.org/10.1080/14606925.2018.1527513

Oxford, R. (1997). Cooperative learning, collaborative learning, and interaction: Three communicative strands in the language classroom. The Modern Language Journal, 81, 443–456. https://doi.org/10.2307/328888

Sands, J., & Worthington, D. (Eds.). (2007). High-level skills for higher value. Design Council. https://fr.calameo.com/read/000046992f06045e4d314

Scallon, G. (2007). L’évaluation des apprentissages dans une approche par compétences (2nd ed.). Éditions du Renouveau pédagogique.
Shepard, L. A. (2000). The role of assessment in a learning culture. Educational Researcher, 29(7), 4–14. https://doi.org/10.3102/0013189X029007004
Stempfle, J., & Badke-Schaub, P. (2002). Thinking in design teams—An analysis of team communication. Design Studies, 23(5), 473–496. https://doi.org/10.1016/S0142-694X(02)00004-2
Stompff, G., & Smulders, F. (2013). Mirroring: The boundary spanning practice of designers. In C. de Bont, E. den Ouden, R. Schifferstein, F. Smulders, & M. van der Voort (Eds.), Advanced Design Methods for Successful Innovation (pp. 144–163). Design United.
Tessier, V. (2020). Insights on collaborative design research: A scoping review. The Design Journal, 23(5), 655–676. https://doi.org/10.1080/14606925.2020.1807716
Tessier, V. (2021). Étude exploratoire sur le travail en équipe d’étudiants dans l’atelier de design: Vers un modèle d’évaluation pour l’apprentissage basé sur la théorie de l’activité et l’apprentissage expansif [Ph.D.]. Université de Montréal. http://hdl.handle.net/1866/25512
Tessier, V., & Zahedi, M. (2019, September 13). Assessment of collaborative design: A sociocultural approach. Proceedings of the 21st International Conference on Engineering and Product Design Education (E&PDE 2019), University of Strathclyde, Glasgow. 12th -13th September 2019. 21st International Conference on Engineering and Product Design Education, Glasgow, UK. https://doi.org/10.35199/epde2019.15
Tucker, R., Abbasi, N., Thorpe, G., Ostwald, M., Williams, S., & Wallis, L. (2014). Enhancing and assessing group and team learning in architecture and related design contexts (p. 110). Office for Learning and Teaching, Department of Education.
Tucker, R., & Reynolds, C. (2006). The Impact of teaching models, groups structures and assessment modes on cooperative learning in the student design studio. Journal for Education in the Built Environment, 1(2), 39–56. https://doi.org/10.11120/jebe.2006.01020039
Vygotsky, L. S. (1978). Mind in society. Harvard University Press.
Zahedi, M. (2019). Integration of novice designers into interdisciplinary teams. ReDes, Lisbon, Portugal.
Zahedi, M., & Heaton, L. (2017). A model of framing in design teams. Design and Technology Education: An International Journal, 22(2), 8–25. https://ojs.lboro.ac.uk/DATE/article/view/2264
Zahedi, M., Tessier, V., & Hawey, D. (2017). Understanding collaborative design through activity theory. The Design Journal, 20(Sup 1), 4611–4620.
Zahedi, M., Tessier, V., & Heaton, L. (2018, November 15). Designerly activity theory insights on the design processes of a Korean company. Tech-Centered Design Thinking. Design Thinking Research Symposium, Korea.

Appendix

Category (zone)		Code (Characteristic)	Factors
1. Personal	1.1	Adaptation to context	A- New to University B- International exchange student
	1.2	Personality traits	A- Situational traits B- Permanent

Category (zone)		Code (Characteristic)	Factors
	1.3	Motivation and engagement	A- Intrinsic motivation B- Extrinsic motivation
	1.4	Trust	A- Self-confidence B- Trust in teammates C- Trust in experts
	1.5	Stress management	A- Personal stress management B- Stress management of others
	1.6	Focus on the project	A- Friendship B- Work environment C- Attention disorder
	1.7	Affirm role or position	A- Communicate a role or skills B- Affirm experience
2. Project	2.1	Project activities	(Not detailed)
	2.2	Expressing ideas	A- Proposing ideas B- Combining ideas C- Fixation
	2.3	Taking initiative	A- Take action B- Passive attitude C- Question or doubt
	2.4	Shared comprehension	A- Share the same vision B- Lack of common vision
	2.5	Feedback on the project	A- Feedback from teacher B- Feedback from peers and colleagues C- Feedback and critics from experts
	2.6	Attention to details	A- Adopt a micro vs macro perspective
	2.7	Project complexity	A- Gap with previous experiences B- Seek peer recognition
	2.8	Project feasibility	A- Search for credible propositions
3. Organisational	3.1	Time management	A- Waste time B- Project organisation C- Time organisation D- Different work rhythms
	3.2	Meeting deadline	A- Project deadlines B- Sub-deadlines imposed by the teacher C- Sub-deadlines self-imposed
	3.3	Tasks management	A- Joint work B- Task division C- Individual work
	3.4	Personal responsibilities	A- Job B- Differing schedules C- Personal priorities
	3.5	Prioritisation	A- Prioritisation (hierarchy)

Category (zone)		Code (Characteristic)	Factors
	3.6	Disciplinary expertise	A- Respect disciplinary zones B- Promote a design approach
	3.7	Team habits	A- Facilitate the project process B- Regressive habits
4. Learning	4.1	Project tools	A- Lack of mastery of basic tools B- Lack of access to tools C- Mastery of complex tools
	4.2	Sharing new information	A- Communication information B- Mutual learning C- Lack of knowledge on an aspect of the project D- Search for external support
	4.3	Complementary skills	A- Skills complementarity B- Work method complementarity C- Strength diversity
	4.4	Inclusion of experts	A- Ask for help B- Base decisions on experts' knowledge
	4.5	Project authenticity	A- Compare pedagogical and professional approaches B- Professional concerns
5. Social	5.1	Getting to know each other	A- Team up with a stranger B- Prejudices C- Team up with friends
	5.2	Communication	A- Good communication B- Lack of communication or tensions C- Remote communication D- Communication with experts
	5.3	Team atmosphere	A- Positive atmosphere B- Avoid clashes C- Act with respect D- Lack of involvement
	5.4	Team hierarchy	A- No hierarchy B- Egalitarian relationship C- Leadership or hierarchical structure
	5.5	Agreeing together	A- Individual decisions B- Common decisions
	5.6	Team meetings	A- Personal responsibilities B- Fixed meetings

Refining a pedagogical approach for employing design thinking as a catalyst

Gudur Raghavendra Reddy, University of Canberra, Australia
Deana McDonagh, University of Illinois Urbana-Champaign, USA
Maurita T. Harris, University of Illinois Urbana-Champaign, USA
Wendy A. Rogers, University of Illinois Urbana-Champaign, USA

Abstract

There is an increasing interest in design and creative thinking processes in the Sciences, Technology, Engineering, and Mathematics (STEM) and health education disciplines. Many new degree programs are integrating design thinking into their syllabi, with the intention of bringing creative problem-solving methods to these disciplines. In reality, the exposure these students get is minimal, and it does not provide enough foundation for them to use the knowledge and apply the process(es) in real-life situations. There is an increased awareness of the importance of design thinking in the innovative process. More and more STEM, business, and health establishments are embedding trained designers into their research teams – yet many designers are not equipped to work on interdisciplinary teams. Design students tend to approach problems more intuitively, opportunistically, and build on creative leaps of imagination whereas, STEM and health disciplines are often more algorithmic, systematic, and rationale. This can often generate tension in interdisciplinary teams, especially when traditional disciplines (e.g., Engineering, Sciences) are integrating relatively newer thinking (e.g., design thinking).

In this paper, we share the outcome of a phenomenological study on a high-functioning interdisciplinary team working on a health innovation project focused on aging with a disability. This case study illustrates the skill set needed for designers, health and technology professionals to make a significant contribution to its overall outcome. We identified key attributes that contribute towards being an effective member of interdisciplinary teams. Based on this study, we propose a pedagogical approach to better equip design, STEM, and Health students to be more competitive in changing economic expectations and ensure more impactful design outcomes.

Keywords

interdisciplinary team, design thinking, design education, STEM education, design research.

Introduction

There is an increasing awareness that design thinking skills play a catalytic role in innovation outside the design domain. This realisation has resulted in an explosion of educational programs that integrated design thinking skills in their respective disciplines. This trend is especially evident in the Sciences, Technology, Engineering, and Mathematics (STEM) and health education disciplines (van der Sanden & de Vries, 2016). There is an awareness that the inclusion of design thinkers in interdisciplinary teams produces much more effective outcomes.

Over the past decade, there has been increasing acknowledgment of encouraging a wider awareness of knowledge while concurrently developing a deeper level of expertise in a particular area. This is referred to as a T-Shaped educational model, expertise in one profession, and awareness of related professions (Baratta, 2017). This educational model facilitates incorporating design and creative thinking skills as part of breadth knowledge and more holistic thinking. These efforts have resulted in an appreciation of design skills and designers in STEM and Health disciplines. However, the attitude and behaviour involved in a problem-solving activity are quite different in these disciplines, which may result in ineffective and unproductive teams.

This case study builds on our earlier research (Reddy, McDonagh, Harris, & Rogers, 2020a) and further explores this phenomenon using a high-functioning interdisciplinary team working on a health innovation project focused on aging with a disability to illustrate the skill set needed for a designer to make a significant contribution in an interdisciplinary team.

Design

> *"The International Council of Societies of Industrial Design gives it credit for creativity, but then complicates it with grandiosity: "Design is a creative activity whose aim is to establish the multi-faceted qualities of objects, processes, services and their systems in whole life cycles. Therefore, design is the central factor of innovative humanisation of technologies and the crucial factor of cultural and economic exchange" …A more recent definition from proponents of design thinking emphasize design as a problem solving that creates new, useful products, places, communications, or experiences."* (Giudice & Ireland, 2013, p. 14)

Definition of design varies immensely based on who is writing about it. This often creates an impression that design as a discipline is superficial and perceived to have a low value. In the context of this paper, we provide few snapshots of design, design thinking, and design attitude to provide a baseline to what we refer to as 'design' and the value of 'design.'

Lawson (2006) described design activity by contrasting how scientists and designers differ in solving a problem. Lawson pointed out that scientists use a strategy to analyse a problem to find an optimal solution systematically. In contrast, designers tend to explore the problem cursorily, and proceed to suggest a variety of solutions, and settle for one that is most satisfactory. In other words, scientists use problem-focused strategies and designers use solution-focused strategies (Cross, 2008).

Nelson and Stolterman (2014) provided further insight by contrasting how scientists, artists, and designers approach their activity. Scientists are extremely focused on precise, accurate, logical, and validated processes so that the outcome of the process can be 'trusted.' Artists are not particularly concerned about the process but are more interested in self-expression and in getting the desired outcome. Designers are focused on both the process and the outcome, aiming to use the process appropriate for the desired outcome in satisfying the needs of others. In other words, for designers, process and outcome are entwined and equally important.

This is why Rittel and Webber (1984) referred to design problems as 'wicked.' Wicked problems do not have a definitive formulation; the problem and solution are linked in such a way as to define the problem, a designer has to attempt a solution (Cross, 2008; Lloyd & Scott, 1994).

Visser (2009) noted that the outcome of a design process has no one definitive solution that can be termed as correct. An ill-defined problem has potentially several acceptable solutions, and designers settle for what they deem the most satisfactory (Simon, 1975).

In short, design is a problem-solving process or an activity towards finding innovative solutions for complex/ill-defined problems. The problems in our case study are the everyday challenges faced by older adults with mobility disability.

Effective Team

Our global and interdisciplinary Design Team originated at the University of Illinois Urbana-Champaign (USA) to collectively design solutions based on the everyday challenges experienced by older adults with a mobility disability. We conducted an archival study to understand these challenges using data derived from the Aging Concerns, Challenges, and Everyday Solution Strategies (ACCESS) study (Koon, Remillard, Mitzner, & Rogers, 2020). Members of the ACCESS team consists of a mix of Community Health, Exercise Science, Gerontology, Human Factors, and Psychology fields all within the USA. The collaboration among these fields brought insight on the design and implementation of a large-scale interview study that collectively illustrated the various challenges those aging with a mobility, vision, or hearing impairment face in their everyday activities, ranging from activities of daily living (e.g., toileting and bathing) to using transportation. In addition to the everyday challenges, the ACCESS study aimed to understand how those aging with a disability respond to their challenges—for example, using technology or receiving help from others.

With the plethora of data from the ACCESS study, our interdisciplinary Design Team came together to understand the challenges those aging with a mobility disability have with transportation due to its association with various aspects of health. A successful team is often a diverse mix of behaviours ("The Nine Belbin Team Roles,"). Our team members came from a mix of Community Health, Empathic Design, Human Factors, and Interaction Design. They bring experience as researchers and educators collectively from the USA, India, United Kingdom, and Australia. Belbin Team Roles stated that there are two parts to any team: first is the functional role, which is the skill-set a person brings to the team. Second is the team role, which is the behaviour of a team member in terms of contribution to its effectiveness (Belbin, 1991). Nine roles can be roughly grouped under three categories: (1) thinking-oriented (Plant, Monitor, Evaluator, and Specialist); (2) action-oriented (Shaper, Implementer, Completer Finishers); and (3) people-oriented (Coordinator, Team Worker and Resource Investigator). Each of these roles plays a critical part during a project life cycle (Belbin, 2010). The following is the involvement of team roles at different stages of a project.

- Ideation – Plant and Resource Investigator
- Evaluation – Monitor Evaluator
- Implementation – Implementer
- Completion and deployment - Completer Finisher

Designers often play the role of a Plant in interdisciplinary teams. Plants can tackle complex problems innovatively through their creative thinking skills. However, they tend to get distracted or may pursue an impractical idea. To make the most out of a Plant you need a

Coordinator who can channel their talents and help keep their ideas aligned with the team's needs. Plants can take leadership roles when supported by a Monitor Evaluator and or an Implementer. Both help keep the Plant rooted in reality. There should not be too many Coordinators or Plants in any team, and they should be involved at the right time of a project life cycle ("Belbin and Project Teams," 2020).

In our Design Team, we have a well-defined Coordinator, focused Monitor, and a Plant. The team is effective because there is minimal overlap in team roles, and they are involved only at the right time of the project life cycle. Most importantly, all the members have experience in working in interdisciplinary teams, as well as a shared goal of supporting older adults with mobility disability.

Case Study Implications for Design Education

This case study illustrates the complexity of finding solutions for wicked problems; the needs for disciplinary diversity of team members; and the team roles required for success. We use this example as the base from which to evaluate design education. Are current approaches to design education providing students with what they need to effectively contribute to teams that are tackling the wicked problems in society? We propose and amend approach that focuses directly on the value of incorporating design thinking.

What is missing in design education?

Design is the driving force of the new economy, illustrated in Table 1, which was adapted from 'Designing a Future Economy: Developing design skills for productivity and innovation" by Design Council (2018). It is well documented that design skills contribute to innovation in a discipline outside of itself. This implies that designers are working in organisations (e.g., health sector, law sector) that are not their traditional destination (e.g., creative industries, design consultancy (Design Council, 2018). What used to be an exception, an unfamiliar career path, is becoming a norm in the current economy.

Competencies expected in the new economy

The changing requirements of the new economy will be expecting a different set of skills from future designers, skills that are not part of their current training. This presents some serious challenges to design education to bridge the skill gaps sooner than later.

Table 1: Future demand for design skills [6]

Skill	Importance to Design Economy occupations (Importance Premium)	Predicted future demand
Operations analysis	23%	22
Fine arts	15%	51
Programming	22%	58
Computers and electronics	5%	60
Geography	4%	61
Visualisation	3%	64
Design	40%	68
Engineering and technology	18%	76
Building and construction	9%	82

Traditionally, the following discipline-specific skills highlight good designer skills and knowledge (Dym, Agogino, Eris, Frey, & Leifer, 2005); additionally, designers are expected to possess the ability to:

- Tolerate ambiguity associated with the interactive process of divergent-convergent thinking,
- Think holistically by switching between micro and macro-level thinking,
- Make decisions in uncertain conditions,
- Think as part of a team,
- Communicate using the appropriate language of design.

What is missing from this list is the skills and knowledge required to work in fields outside of traditional establishments. Skills that are essential for career progression and taking on leadership roles in an establishment.

As an example – we are already seeing transition in skill requirements. what used to be defined as 'graphic design' is today referred to as 'UX design'. LaBarre (2016) wonders if tomorrow these UX designers be avatar programmers, fusionists, and artificial organ designers?

> *"A new wave of designers formally educated in human-centered design—taught to weave together research, interaction, visual and code to solve incredibly gnarly 21st-century problems." (Miller,cited in LaBarre 2016). (LaBarre, 2016)*

Similarly, recent research shows how STEM areas are realising importance of 'design' in their professional practice (Petrina; Semouchkina, 2021). It is imperative both Design and STEM education should address the growing demand for both interdisciplinary hard skills and soft skills such as ability to work and communicate in teams with diverse disciplinary members.

STEM to STEAM

> *"In the Western tradition, the right answer was soon identified as an outcome of rational thought, using the protocols of the scientific method." (Nelson & Stolterman, 2014, p. 30)*

Research suggests that the inclusion of arts education in STEM curriculum can positively impact students' creative and critical thinking abilities. It is also known to improve abstract thinking skills, spatial reasoning and openness to new ideas, which are qualities that are essential for innovative problem solving (Perignat & Katz-Buonincontro, 2019).

STEM fields are adopting art and design pedagogy to enhance creative thinking skills in technological disciplines (Costantino, 2018). With the addition of art and design to the technological disciplines, capital 'A' was introduced into STE'A'M. STEAM curriculum adoption in high schools is increasing drastically and is already producing positive results. One of the most visible outcomes is an increase in design awareness and its importance in the technology development process. This trend is resulting in an increased presence of designers in traditional STEM establishments. Although STEAM curriculum increases awareness and importance of creative thinking in STEM areas, it does not impart a depth of knowledge for its practical implementation. Nor does it fully prepare to work with designers in interdisciplinary teams.

Designers often in a Plant role with a 'work alone' attitude find it hard to get accepted into teams that are not aware of their behaviour or value ("Belbin and Project Teams," 2020). Similarly, such work-alone Plants find it hard to cope with a structured way of doing things. Further, design and the other creative fields tend to attract more visual thinkers. Often those who have struggled with the traditional forms of communication (e.g., written word). From the authors' experience, up to 30-40% of design students tend to have varying degrees of dyslexia and increasingly attention deficit disorders.

> *"People who are dyslexic seem to have an abundance of creative thought."Shaywitz cited in Rhodes (2016).*

Although this may sound alarming to those outside of design, it is a good indicator of their ability to identify the lived experience slightly differently and offer unique solutions that a more traditional thinker may not offer and problem-solving. They tend to view the end goal rather than the incremental steps in the process. Being 'wired' differently is an advantage when your goal is to reimagine how the lived experience could (and should) be.

Most of these issues can be resolved through proper training and experience. However, most design curricula are situated in an intensive creative environment that encourages students to adopt individualism and gut feelings towards problem-solving. Thus, Plants emerging from these environments are often not good at communicating in a language appropriate for an interdisciplinary setting. This approach, at times (and to non-designers), may appear unrealistic and irrational as we move towards more interdisciplinary solutions. There is already a realisation of these limitations, and there are numerous examples of integrated programs where design and technology students work together (Nae, 2017). The integrated learning environment is often extremely design-specific, where technology students get immersion in design programs rather than the other way round. As a pilot program, authors have run an integrated course for design and technology students at the University of Canberra. As expected, technology student enrolments outnumber design students by 9:1 over two consecutive years. In the new MS in Health Technology program at the University of Illinois Urbana-Champaign, students have primarily enrolled from either engineering or behavioural science backgrounds, not design. However, they are encouraged to take design courses as electives to integrate design thinking in their capstone projects.

Whereas the emerging new breed of the STEAM cohort is adapted to working in interdisciplinary teams, sadly, designers in this cohort are still not adequately equipped to work in these environments.

Design thinking and STEAM Leadership

> *"Now that companies need agility and imagination, in addition to analytics, we believe it's time to turn to Design as a model of leadership." (Giudice & Ireland, 2013, p. 13)*

The growing importance of design-thinking to identify and solve complex problems has greatly influenced the perception of its significance and contribution to the economy. Thus, transforming 'design' into a new pathway to leadership roles. This change in perception is opening up new leadership roles for designers within both business and education. Giudice and Ireland (2013, p. 17) identified six defining characteristics of design leaders; Change Agents, Risk Takers, Systems Thinkers, Intuitive, Socially Intelligent and, GSD ("gets shit done").

The opportunities and advantages presented by design thinking are well understood by STEM and Health areas. Furthermore, they have realised that their education programs lack training in creative thinking and the ability to deal with ambiguity. However, they address the gap in their discipline by introducing art and design subjects into their education programs, especially programs at the high school level where there is a significant amount of work underway (Bequette & Bequette, 2012).

STEAM Limitations

STEAM curriculum increases awareness and importance of creative thinking in STEM areas; however, it does not provide enough immersion to integrate the knowledge organically. Most importantly, the current STEAM curriculum is not integrated deeply enough to dispel stereotypes about design practice being superficial (i.e., design is just about styling, defining form, colour). This could also be due to a lack of clear understanding difference between Art and Design. Although both Art and Design share similar creative thinking strategies, Art is more focused on producing experiential/aesthetic artifacts. On the other hand, designers are more engaged in using the design-thinking processes to solve complex problems.

Adding designers to interdisciplinary teams does not necessarily solve the problem. The imbalance of perceived value of the contribution by designers needs to be corrected first. Moreover, value perception is essential for a 'welcoming and respectful culture' for designers when engaging with engineers, scientists and technologists.

STEM to STEMHD (emerging discipline)

Art education in STE'A'M provides insights into the creative thinking processes. However, Design education is needed to use creative processes in solving complex problems. Further, the Health / Medical discipline is currently grappling with wicked problems, where the importance of design thinking is felt strongly. Perhaps the STEM needs to be expanded its scope to reflect current needs - Science, Technology, Engineering, Math, Health and Design (STEMHD). The following are a few examples that supports a need for more STEMHD education.

In the Human Factors and Aging Laboratory (HFAL; www.hfaging.org), the members are from multiple disciplines and all research project teams are intentionally interdisciplinary to benefit from different modes of thinking and problem-solving approaches. Since inception, the field of human factors has been interdisciplinary, with the goal of "optimizing human performance in systems and reducing errors by designing those systems to accommodate the capabilities and limitations of humans from a perceptual, cognitive, and physical perspective (Rogers & McGlynn, 2019, pp. 1-16). Consequently, by definition, design thinking should be incorporated into human factors research and application. Current members of HFAL project teams hail from architecture, biomedical engineering, communications, education, gerontology, industrial design, industrial engineering, informatics, media, nursing, occupational therapy, psychology, public health, speech, and social work. The following two examples illustrate the role of design thinking.

First is the ACCESS project, previously described. This large corpus of data was collected to understand the everyday activity needs of people who are aging with long-term perceptual and physical disabilities. The impact of this understanding is best realized with engagement of designers to interpret those data through their unique lens. For example, our Interdisciplinary Design Team has utilized the qualitative interviews as "sparks of innovation" to transform challenges into opportunities (Reddy, McDonagh, Harris, & Rogers, 2020b). In addition, an architecture student has been evaluating the interview data to develop environmental design solutions (Ramadhani & Rogers, 2020).

The second example is in the context of human-robot interaction (HRI) with mobile-manipulator robots to support older adults in their home. Early work with a large, heavy, expensive robot called the PR2 established the potential value of domestic robots that could support everyday activities (Beer et al., 2017; Smarr et al., 2014). The next generation of design for a mobile manipulator robot has been developed by Hello Robot and is called Stretch (https://hello-robot.com/). The interdisciplinary HRI team incorporated design thinking and problem-solving approaches to develop a smaller, lighter-weight, less-expensive, but similarly functional robot; see Kadylak et al. (in press) for initial human factors evaluations. We are currently using the case-study approach often incorporated in the design field to garner an in-depth understand of the unique needs of one person who has quadriplegia, and his care partner, to guide the next iterations of the tools that Stretch should be outfitted with to support functional independence for a variety of tasks. We advocate the participatory design approach as potentially very useful for HRI advancements (Rogers, Kadylak, & Bayles, in press).

The above examples clearly demonstrate how an interdisciplinary team is the need of the hour. The current culture in the industry expects that working in interdisciplinary teams is a given, and our students should be prepared for the challenges this form of collaborative working expects. Both design and STEM curriculum needs to align with the changing nature of the workforce. In this regard, recent experiments on integrated bachelor's degrees are in the right direction, but much more needs to be done. Most of these programs have addressed limitations in interdisciplinary knowledge (functional role). The problem has another facet – attitude (team role). Attitude and resulting behaviour are deciding factors of a person's role in a team.

Interdisciplinary Education

Although we are seeing progressively more awareness in multiple disciplines about design, design education is yet to catch up with preparing their students in return. Figure 1 illustrates the gradual overlap of disciplines that we are seeing in practice. This pattern is not yet reflected in preparing the future workforce.

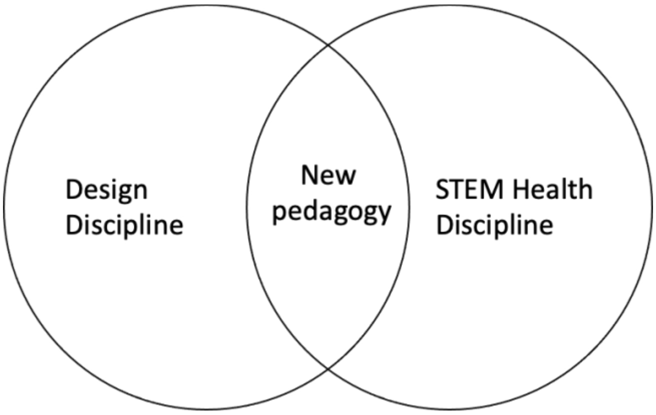


Figure 1: The intersectionality of STEM, Health disciplines, and design to create a new interdisciplinary design pedagogy approach for design students.

A current challenge in interdisciplinarity in design and STEM+Health education is that it is restricted to individual courses and their instructors. Its benefits are largely dependent on students' openness to the idea, their profile, and aptitude to make sense at a macro level (Self, Evans, Jun, & Southee, 2019). The new curriculum must address this at the systemic level to change the complete outlook of the program.

Design Mindset

> *"To be a practicing designer therefore is not only a matter of skill and knowledge. Design praxis also requires personal integrity and proficiency, in conjunction with a design process that is compatible with and reflective of the designers' character and competence." (Nelson & Stolterman, 2014, pp. 239 - 240)*

Michlewski (2016) made an important distinction between design thinking and design attitude. Meaning, a design-attitude approach to problem-solving cannot be compared with using a process such as a design-thinking toolkit. Design attitude is a frame of the mind of a person who uses the design-thinking process to produce the intended results. Design attitude is a way of being that forms part of professional culture of designers inculcated through deep immersion or "situated learning." Michlewski (2016) identified five distinctive aspects of 'designer attitude'.

1. Embracing uncertainty and ambiguity
2. Engaging deep empathy
3. Embracing the power of five senses
4. Playfully bringing things to life
5. Creating new meaning from complexity

For a designer, ‘design attitude’ or ‘design mindset’ is a defining factor that cannot be negotiated. Design attitude encourages working towards solutions that are "assertion-based” rather than “evidence-based.” Emphasis is more on proposing novel solutions that challenge the status quo (Michlewski, 2008). On the other hand, for a researcher, the ‘scientific attitude’ is more evidence-based, objective observation and not concluding anything that is not based on or supported by facts (Rao, 2010).

In an interdisciplinary team, we see these two contrasting attitudes work together towards a common goal. To work on an interdisciplinary team, one needs to be prepared and equipped to switch their thinking approaches based on their team role (De Bono, 2017). The skills required to be flexible in thinking approaches are missing from the current design curriculum. To help acquire these skills, the proposed design pedagogical approach will extend the cliched T-skill model by developing attitudinal skills as part of their breadth-knowledge.

STEMHD Pedagogy Approach

Taking from Edward De Bono’s six thinking hats (De Bono, 2017) encourages one to think outside the comfort zone and gain an empathic point of view. The proposed pedagogical approach encourages students to take a breadth of courses in the discipline in a much more structured fashion, from introductory courses to a level that allows them to gain adequate skills and knowledge. Finally, leading to capstone projects where they are encouraged to adapt attitudinal thinking of breadth discipline through ‘situated learning.’ Meaning, if a design student is taking an ‘Introduction to Programming’ course, they will play the role of a programmer in a collaborative project. Similarly, a programming student in a design course will take on the role of a designer.

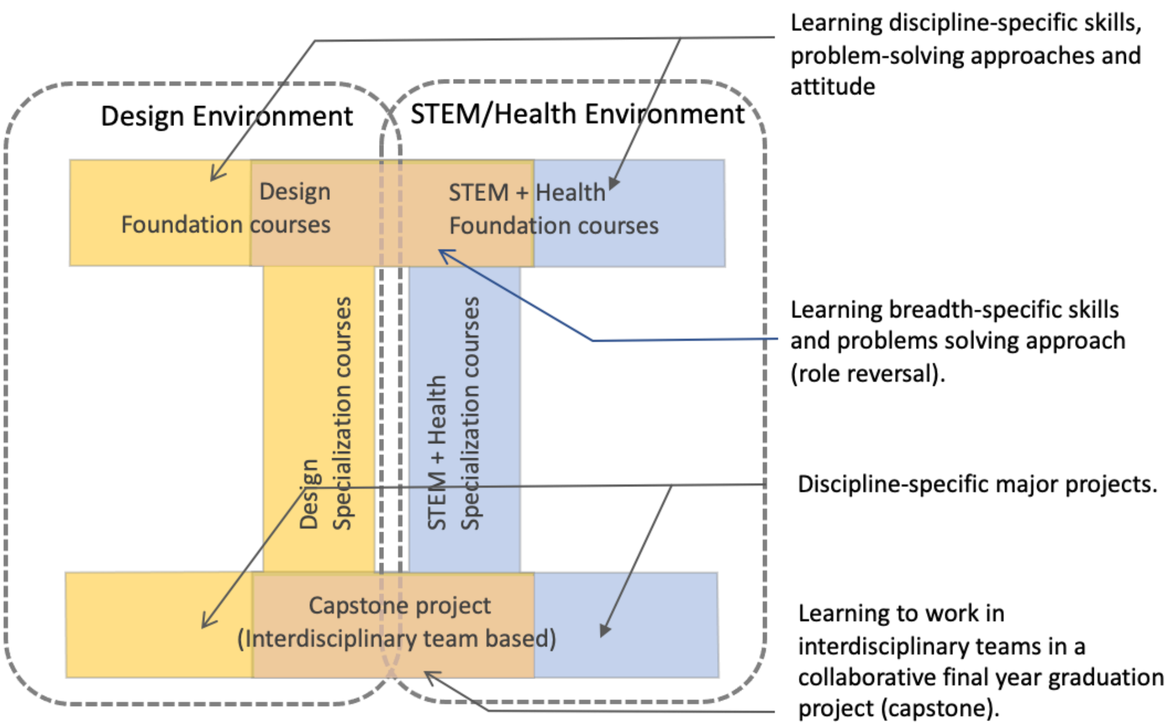


Figure 2: Possible plan for integrated courses – STEM to STEMHD

Figure 2 illustrates an approach that we put in place based on our early experimentation with a three-year Bachelor of Design and Bachelor of Information Technology degrees as well as Master of Science in Health Technology (MS-HT). The overall journey will go through the following milestones:

1. Learning discipline-specific skills, problem-solving approaches and attitude.
2. Learning breadth-specific skills and problems solving approach. Learning how to apply breadth-specific problem-solving approaches and attitude (role reversal). For example, IT student take foundations courses in design (Design thinking, Visualization and prototyping, Introduction to interaction design, etc.)
3. Learning to work in interdisciplinary teams in a collaborative final year graduation project (capstone). For example, IT students take supervised group projects – where groups of students will work with either student team member from design discipline or work with supervisor from design discipline. MS-HT students complete a capstone that is sponsored by an industry, community, or faculty partner.

Discussion

The pedagogical approach we are currently working with is intended to give students enough time to inculcate professional cultural attitudes through situated learning. However, as Nelson and Stolterman (2014, p. 33) noted:

> *"If a designer chooses a scientific approach, the whole design process will have strong similarities to a research process. This will limit or eliminate not only what is considered to be the preconditions of design, but also what is possible, what is needed, what is*

desired, and what the eventual outcome will be. It will no longer be a design process." (Nelson & Stolterman, 2014, p. 33)

The intention is not to turn a designer into a scientist or vice-versa. It is about having the depth of awareness to appreciate alternative approaches to problem-solving as against – tolerating the existence of alternative ways of problem-solving.

To validate our proposed pedagogical approach, we are offering a set of foundational design courses to Bachelor of Information technology students to help them learn breadth specific skills and problem-solving methods. In addition, offer few capstone projects for final year students to immerse them into interdisciplinary teamwork experience. In this instance, the capstone project problems are framed by the supervisors. Each team comprises two to three students under one to two supervisors. All teams should have an embedded designer who is either a student or a supervisor. The student feedback from the past two semesters showed us that this experience widened their outlook on solving complex problems. The following quotes are from the feedback of our current student group.

"... This unique opportunity to have sponsors from two separate disciplines has been greatly beneficial to the overall project. Dr Raghu provides guidance in terms of the design methodology of the system and Dr Masoud handles the technical aspects required to bring the project to fruition. They have made this project an absolute pleasure as they provide consistent support and encourage me to explore new ideas. A multidisciplinary team is exceptionally constructive as it provides a broader perspective and allows us to expand our vision beyond a particular discipline/mindset. As the capstone project is designed to give students the skills to solve a real-world problem, a greater school of thought is mandatory to ensure the success of any project … Having capstone supervisors from different schools have helped us garner creative visual ideas in multiple perspectives and exposure to several types of design methodologies…"

We have been investigating our proposed pedagogical approach over the past three semesters. Meaning, we still have not seen its full impact as students who have done foundational design units will only enter final year capstone projects next year. In parallel, design students from Bachelor of Design taking foundational Information Technology courses will be ready to join the capstone projects as embedded designers.

Conclusion

Acknowledging that interdisciplinary teamwork is becoming the standard in the industry as the STEM and Health fields are increasingly integrating designers into their teams. This both presents a challenge and an opportunity for design, STEM and Health education and the industry. It is no longer enough to gain knowledge the traditional way without being a highly functioning team member in an interdisciplinary work environment.

Designers are often the most equipped to humanise technology by integrating the supra-functional needs that complement the training of functional needs by engineers, scientists, and technologists. However, functioning in an interdisciplinary environment with conflicting approaches to problem-solving could be challenging. As we have observed in our own team experiences, conflicts may result from differences in working styles and behaviours. In this regard, the Belbin team performance model provided us with an insight into how a successful team is built on a balance of team and function roles. The team role is based on human aspects such as attitude and behaviours, and the functional role is necessary to fulfil a profession-based task. Most importantly, variations can be used constructively in an interdisciplinary team.

The traditional design and STEM curriculum effectively provide functional skills, and many recent integrated courses, including breadth subjects, help understand the importance of complementary skills. However, learning breadth skills alone does not provide soft skills to effectively function in interdisciplinary teams with diverse thinking and working styles.

This paper highlights the importance of team roles in an effective team member in an interdisciplinary work environment and presents a STEMHD pedagogical approach to provide these implicit skills through immersion. The outcome of the STEMHD pedagogical approach implemented in our case study over three semesters has shown promising results. Students' feedback from capstone projects further provides confidence in the success of STEMHD prelogical approach in addressing the growing demand for graduates trained to solve wicked problems the current economic reality expects.

Acknowledgment

This research was supported by the National Institute on Disability, Independent Living, and Rehabilitation Research (NIDILRR grant number 90REGE0006-01-00) under the auspices of the Rehabilitation and Engineering Research Centre on Technologies to Support Aging-in-Place for People with Long-Term Disabilities (TechSAge; www.TechSAgeRERC.org).

References

Baratta, D. (2017). The "T" shaped designer expertise. The "reverse-T" shaped designer horizon. The Design Journal, 20(sup1), S4784-S4786. doi:10.1080/14606925.2017.1352992

Beer, J. M., Prakash, A., Smarr, C.-A., Chen, T. L., Hawkins, K., Nguyen, H., . . . Rogers, W. A. (2017). Older Users' Acceptance of an Assistive Robot: Attitudinal Changes Following Brief Exposure. Gerontechnology : international journal on the fundamental aspects of technology to serve the ageing society, 16(1), 21-36. doi:10.4017/gt.2017.16.1.003.00

Belbin and Project Teams. (2020).

Belbin, M. (1991). Design Innovation and the TEAM. Design Management Journal (Former Series), 2(3), 38-42. doi:10.1111/j.1948-7169.1991.tb00575.x

Belbin, M. (2010). Management teams: Routledge.

Bequette, J. W., & Bequette, M. B. (2012). A place for art and design education in the STEM conversation. Art education, 65(2), 40-47.

Costantino, T. (2018). STEAM by another name: Transdisciplinary practice in art and design education. Arts education policy review, 119(2), 100-106.

Cross, N. (2008). Engineering design methods : strategies for product design (4th ed.). Chichester, England ; Hoboken, NJ: John Wiley & Sons.

De Bono, E. (2017). Six thinking hats: Penguin UK.

Design Council. (2018). Designing a Future Economy: developing design skills for productivity and innovation.

Dym, C. L., Agogino, A. M., Eris, O., Frey, D. D., & Leifer, L. J. (2005). Engineering design thinking, teaching, and learning. Journal of Engineering Education, 94(1), 103-120.

Giudice, M., & Ireland, C. (2013). Rise of the DEO: Leadership by Design: New riders.

Kadylak, T., Bayles, M. A., Galoso, L., Chan, M., Mahajan, H., Kemp, C., . . . Rogers, W. A. (in press, 2020/12/01). A human factors analysis of the Stretch mobile manipulator robot. Paper presented at the Proceedings of the Human Factors and Ergonomics Society Annual Meeting.

Koon, L. M., Remillard, E. T., Mitzner, T. L., & Rogers, W. A. (2020). Aging Concerns, Challenges, and Everyday Solution Strategies (ACCESS) for adults aging with a long-term mobility disability. Disability and Health Journal, 13(4), 100936.

LaBarre, S. (2016). The Most Important Design Jobs Of The Future. Fast Company. Retrieved from https://www.fastcompany.com/3054433/the-most-important-design-jobs-of-the-future

Lawson, B. (2006). How designers think : the design process demystified (4th ed.). Oxford: Architectural Press.

Lloyd, P., & Scott, P. (1994). Discovering the design problem. Design Studies, 15, 125-125.

Michlewski, K. (2008). Uncovering Design Attitude: Inside the Culture of Designers. Organization Studies, 29(3), 373-392. doi:10.1177/0170840607088019

Michlewski, K. (2016). Design attitude: Routledge.

Nae, H.-J. (2017). An Interdisciplinary Design Education Framework. The Design Journal, 20(sup1), S835-S847. doi:10.1080/14606925.2017.1353030

Nelson, H. G., & Stolterman, E. (2014). The design way: Intentional change in an unpredictable world: MIT press.

The Nine Belbin Team Roles. Retrieved from https://www.belbin.com/about/belbin-team-roles

Perignat, E., & Katz-Buonincontro, J. (2019). STEAM in practice and research: An integrative literature review. Thinking Skills and Creativity, 31, 31-43. doi:10.1016/j.tsc.2018.10.002

Petrina, S. DESIGNERLY WAYS, MEANS, AND ENDS: FROM STEM TO STEAM TO STEAMD.

Ramadhani, W., & Rogers, W. (2020). Ageing in place among older adults with long-term mobility disability: Archival study to understand activity challenges in the home environment. Paper presented at the 2019 IAPS Symposium Ageing in Place in a World of Inequalities: How to Design Healthy Cities for All—Book of Abstracts.

Rao, D. B. (2010). Scientific attitude, scientific aptitude and achievement: Discovery Publishing House.

Reddy, R. G., McDonagh, D., Harris, M. T., & Rogers, W. A. (2020a). Design as a catalyst: A pedagogical framework. Paper presented at the DS 104: Proceedings of the 22nd International Conference on Engineering and Product Design Education (E&PDE 2020), VIA Design, VIA University in Herning, Denmark. 10th-11th September 2020.

Reddy, R. G., McDonagh, D., Harris, M. T., & Rogers, W. A. (2020b). Sparks of innovation: transforming challenges into opportunities. Paper presented at the 6th International Conference on Design 4 Health 2020.

Rhodes, M. (2016). Dyslexic Designers Just Think Differently—Maybe Even Better - Yale Dyslexia. Retrieved from https://dyslexia.yale.edu/dyslexic-designers-just-think-differently-maybe-even-better/

Rittel, H. W. J., & Webber, M. M. (1984). Planning problems are wicked problems. In N. Cross (Ed.), Developments in Design Methodology (pp. 135-144). Chichester: John Wiley & Sons.

Rogers, W. A., Kadylak, T., & Bayles, M. A. (in press). Maximizing the benefits of participatory design for human robot interaction research with older adults. Human Factors. .

Rogers, W. A., & McGlynn, S. A. (2019). Human Factors and Ergonomics: History, Scope, and Potential. In Human Factors and Ergonomics for the Gulf Cooperation Council (pp. 1-16): CRC Press.

Self, J. A., Evans, M., Jun, T., & Southee, D. (2019). Interdisciplinary: challenges and opportunities for design education. International Journal of Technology and Design Education, 29(4), 843-876.

Semouchkina, V. (2021). Advancing Visual Design Culture in STEM Lab Groups. University of Washington,

Simon, H. A. (1975). Style in design. Paper presented at the Edra Two: Proceedings of the Second Annual Environmental Design Research Association Conference, October 1970, Pittsburgh, Pennsylvania.

Smarr, C. A., Mitzner, T. L., Beer, J. M., Prakash, A., Chen, T. L., Kemp, C. C., & Rogers, W. A. (2014). Domestic Robots for Older Adults: Attitudes, Preferences, and Potential. Int J Soc Robot, 6(2), 229-247. doi:10.1007/s12369-013-0220-0

van der Sanden, M. C. A., & de Vries, M. J. (2016). Innovation in Science and Technology Education and Communication through Design Thinking. In M. C. A. van der Sanden & M. J. de Vries (Eds.), Science and Technology Education and Communication: Seeking Synergy (pp. 129-145). Rotterdam: SensePublishers.

Visser, W. (2009). Design: one, but in different forms. Design Studies, 30(3), 187 - 223. Retrieved from DOI: 10.1016/j.destud.2008.11.004

Soft skills in design education, identification, classification, and relations: Proposal of a conceptual map

Ana Paula Nazaré de Freitas, Pará State University (UEPA), Brazil
Rita Assoreira Almendra, Faculty of Architecture, University of Lisbon, CIAUD, Portugal

Abstract
Soft skills are interpersonal, social, and emotional competencies, transversal to various fields of knowledge and life. In the Knowledge Age, soft skills play an essential role in the differentiation of human work. Nevertheless, in design education, there are still few studies on soft skills. This study brings a conceptual map of soft skills in design education. It refers to a mixed-methods research conducted through a survey involving 93 teachers of high education design courses in 26 countries. We combined the survey results with a literature review analysis aimed at defining constructs and identifying their relationship. Finally, we propose a classification for soft skills as being Collective/Individual and Cognitive-Metacognitive/Interpersonal-Social. Our research recognises the connections and interdependence among skills, allowing us to settle different groups and establish relations among other skills. Furthermore, based on literature, we identified a hierarchy of gateways skills and high order skills and pointed out their connections. Additionally, a conceptual map was created, including the 20 primary soft skills in design education, their proposed classification, and the links between the skills. The result can help teachers and students know the primary soft skills in design education and develop teaching-learning approaches to acquire soft skills during their university training.

Keywords
Soft skills, 21century skills, life skills, design education, teaching design

Introduction: The importance of soft skills in design education
Soft skills are interpersonal, social, and emotional skills. They are transversal to various fields of knowledge and life. There are different labels to refer to these skills: 21-century skills (Organisation for Economic Co-operation and Development [OECD], 2005), life skills (World Health Organization [WHO], 1994), generic skills (Virtanen & Tynjälä, 2018), or key skills (Rychen & Salganik, 2003). Despite the various names and the lack of consensus in the literature on their classification, employers have increasingly sought these skills (Majid et al., 2012; Succi & Canovi, 2020). For this study, we use the proposition: "Soft skills represent a dynamic combination of cognitive and meta-cognitive skills, interpersonal, intellectual and practical skills." (Haselberger et al., 2010, p.73). They are often related to working in groups, thinking systematically, collaborating, and developing self-regulation and socio-emotional skills. They are referred continuously as differentiators in the contemporary context (Rychen, 2016; OECD, 2009), characterised by increasing complexity, constant change in everyday life, and technological advancement that gradually replaces human labour with algorithms (Harari, 2018). At the same time, the number and complexity of the crises we have to deal with are growing: the economic crisis, the environmental crisis and recently, the health crisis. These

realities require increasingly resilient, flexible, adaptable, and emotionally intelligent individuals.

Faced with this scenario in which modern development concepts are no longer sufficient to explain and direct human action, it is necessary to question the teaching-learning models, contents, and skills intended to be developed in young people in training. Many studies have highlighted the importance of developing personal, emotional, and subjective skills. In design education is not different; there is a need to update teaching as well as the skills needed by designers of the 21st century has been indicated by researchers in the field (Meyer & Norman, 2020; Norman, 2010; Friedman, 2012; Frascara, 2018; Findeli, 2001). Design schools need to train students in complex thinking (Norman, 2010), teaching research skills, and emphasising interdisciplinary, teamwork, and work anchored in reality (Frascara, 2018). Norman argues that the problems of the contemporary design context involve constantly changing relationships, and consequently, we deal with multiple interdependent variables. Davis (2017) advocates the need for new design educational paradigms that break with modern design schools' traditions and focus on intellectual flexibility and human values.

There are few studies on soft skills in design education[1] (Freitas & Almendra, in press) despite the growing need to train critical and empathetic designers who work collaboratively and have a systemic vision. Furthermore, faced with technological changes that impact the labour market, it is necessary to train designers who are increasingly flexible and prepared for the constant changes in this market, enabling them to adapt quickly to the individual's changing needs in the contemporary global context. So, in the context of contemporary design work, in which professionals must develop user-centred solutions and integrate increasingly multidisciplinary teams, soft skills are competencies that must be taught in higher education courses.

In a recent study conducted by Spitz (2021) to examine how the international community construes the future of design education, interpersonal communication skills were highlighted as a central component of design education. The necessity of learning critical thought, empathy and teamworking were also pointed out. The study also pinpointed the importance of lifelong learning "supported by a stronger interlocking of practice and education." (Spitz, 2021, p. 21).

Frascara (2018) states the importance of various soft skills such as:

- empathy, necessary to get to know users
- systematic thinking, "capable of discovering connections, differences and similarities in complex problems, beyond the usual"2 (Frascara, 2018, p. 22)
- teamworking, to form interdisciplinary teams and manage interpersonal relationships to improve their performance with the team and with customers

[1] In a systematic study in 2019, we identified only 11 articles that mentioned soft skills in design education.

[2] In the original: "(...) capaz de descobrir conexiones, diferencias y similitudes em problemas complejos, por encima de lo habitual"

In other words, to be a good designer, it is essential to understand society, culture, history and people's behaviour dynamics and develop soft skills. To achieve this educational purpose, the author suggests using the problem-based approach.

Problem-based education has emerged as a frequent pedagogical practice in studies on the teaching and learning of soft skills (England et al., 2020; Virtanen & Tynjälä, 2018). This type of pedagogical approach brings students closer to reality, enabling them to face problems in a complex way rather than in a controlled and falsely simplified context (Frascara, 2018). It is an approach stemming from critical pedagogy, which proposes to see education as a transformative practice and emphasises subjects' autonomy as builders of their knowledge through a dialectical method between individuals and the environment (Freire, 1997). In this approach, learning is seen as a multi-factorial process that varies from subject to subject. It is characteristic of being starred by the learner, having it as the centre of the process. (Moran, 2018).

Problem-based education is a kind of Active methodology. This approach is different from the deductive methods, which are teacher-centred and based on the teacher's transmission for later application by the student. The Active Methodologies are learning strategies centred in the student role; they may be hybrid and combine different methods. These methodologies have been indicated as favourable to the development of soft skills (Virtanen & Tynjälä, 2018) as they provide contextualised learning, increase protagonism and student participation, continued teacher training, flexibility and can be integrated and less dependent on disciplinary curricula (Moran, 2015). To this teaching approach, the professor has to convey their role as information providers to facilitators guide

> *The key elements of active learning are student involvement in the learning process and critical reflection on course material. Unlike the teacher-centred approach, where students simply listen to lectures and take notes, in active learning, students engage with the course material, participate in the class, and collaborate with others. The process affords students the opportunity to explore and develop new concepts through meaningful discussions and problem-solving situations. (Frey, 2018, p. 2).*

Active learning uses real problems contexts and promotes social interactions. The students have to work collaboratively. These characteristics allow peer learning and promote the increase and the growth of soft skills (Kember & Leung, 2005)

This research aimed to understand the perception of design teachers about the importance of soft skills in design, measuring the importance and weight that each one attributes to all of the proposed skills. We also surveyed the methods that professors use to teach these skills and classified them. We created a conceptual map about soft skills in Design Education that brings an arrangement and visualises their relations from the results. We also identified some pedagogical practices and strategies in design teaching to enable students' skills development.

Methods

This is quantitative and qualitative research. It has been developed through a literature review about competencies and combined with a questionnaire survey. We based this study on the results of a systematic review of literature carried out previously. In this review, we analysed the soft skills related to design studies that identified 49 skills. We selected the 17 most cited skills and added three skills identified by the OECD (2018) as necessary to face the challenges of the 21st century. The skills added from the OECD report were Curiosity, Learning to Learn and Systematic Thinking. We selected these competencies because they were cited by more than one study in the systematic review. Next, we observe the competencies indicated by the OECD that were not included among the 17 identified in the previous study.

The survey was mainly composed of closed-ended and scale questions. The main question was about the importance of soft skills, where the teacher was asked to assess the level of contribution of each skill to the teaching subjects in the design course. These questions used the Likert Scale and asked teachers to evaluate the importance of the skills for the topics they taught, indicating 1 for not contributing, 2 for contributing little, 3 for contributing sometimes, 4 for contributing and 5 for contributing a lot. The last part of the questionnaire asked if the professors used any methodological practices that enable teaching soft skills and if so, the teacher was asked to describe the approach. In this last question, the answers were open.

The research was carried out with professors who work in higher education courses in design. The sampling was non-probabilistic, and we used two techniques to compose: the snowball technique and the targeted mailing technique. The snowball technique consisted of sending the questionnaire by email to some teachers working in design courses requesting them to send it to other teachers involved in design education. The method of targeted mailing happened by identifying several design courses in several countries and contacting them by email. We also identified researchers using the mailing list of some design conferences. We sent 432 emails containing the link to the questionnaire, which resulted in 93 responses.

Results

Literature review results

In the previous study cited, we identified that competencies are usually mentioned without defining the constructs. For this reason, we aim to define the constructs on the competencies operated in the study. This research resulted in table 1 that shows the definitions in a summarised way.

Table 1. Soft Skills operated in the study and its conceptual definitions

Communication: to understand and make oneself understood through exchanges of messages (van Dijk & van Deursen, 2014, p. 2).
Critical Thinking: To reason well, construct and evaluate various arguments, data, reasons and inferences (Paul & Elder, 2007, p. 6).
Creativity: To go beyond what exists today and to generate and implement new ideas (Ward, 2004, p. 175-176).
Problem Solving: To overcome obstacles and move from an initial state to a target state (Chicago State University, 2020).
Curiosity: The desire to learn or know about everything; Ability to be inquisitive (Baxter & Switzky, 2008, p.460).
Research and Exploration: Multifaceted competence allows one to know objective reality through scientific instruments and to have reliable information about it (Prokhorchuk, 2014, p. 442).
Decision Making: To follow normative principles when making decisions (Parker et al., 2018, p.380).

Open-Mindedness: The ability to be receptive to emerging possibilities, share ideas, and consider different perspectives (Cegarra-Navarro & Cepeda-Carrión, 2008, p. 196).
Systematic Thinking: The ability to observe, think, model, simulate, analyse, design and synthesise components, functions, connections, structures, inter-relationships and dynamics between disciplines, processes, organisations, people, trends and cultures (Gallón, 2019, p. 1).
Empathy: Ability to take on the other person's role and imagine the situation from their perspective (OECD, 2005, p. 12).
Collaboration: The ability to participate in the process of shared creation (John-Steiner, 2011, p. 222).
Participation: Ability to participate in or be involved in something (Cambridge Dictionary, 2020).
Flexibility/Adaptability: The ability to produce thoughts from different perspectives or to change approaches to problem-solving (Kaya, 2020, p.505).
Learning to Learn: Ability to pursue and persist in learning, to organise one's own knowledge (European Council, 2006, p.16).
Teamworking: The ability to work together, communicate effectively, anticipate, and meet each other's demands, and inspire confidence, resulting in coordinated collective action (Salas & Cannon-Bowers, 2001, p. 15489).
Self-direction/ Self-management: Ability to regulate your emotions, thoughts and behaviour effectively in different situations (Transforming Education, 2014, p. 1).
Ethic/Compromise: The ability and willingness to be moral, to consider the needs, goals, and perspectives in their own decisions (Menzel, 2016, p.30).
Judgement: The ability to form valuable opinions and make good decisions (Cambridge Dictionary, 2020).
Leadership: Ability to exert influence on others through behaviour or action (Mumford & Gujar, 2020, p. 33).
Entrepreneurship: The ability to create new businesses, products, services, values and/or a state of mind that thrives on innovations with the potential to improve the lives of many people/customers (Parthasarathy, 2011, p. 461).

Survey results

The majority of teachers, 49%, said they worked in Europe, followed by 33% in South America. Other continents such as North America, Oceania, Asia, and Africa were also indicated. The countries that were most cited were Brazil and Portugal. Some teachers answered that they teach in more than one country.

Table 2. Countries indicated by research participants

Country	**Percentage of participants**	**Country**	**Percentage of participants**
Brazil	30%	United States	2%
Portugal	19%	South Africa	2%
The Netherlands	10%	Australia	1%
United Kingdom	5%	New Zeeland	1%
Italy	5%	Czech Republic	1%
Canada	4%	Denmark	1%
México	4%	Ireland	1%
Chile	3%	Switzerland	1%

Turkey	3%	Peru	1%
Belgium	2%	China	1%
Germany	2%	India	1%
Poland	2%	South Korea	1%
Colombia	2%	Singapore	1%

75% said they knew about soft skills, and 25% said they did not realise soft skills. The question that sought to evaluate the average ranking of soft skills asked teachers to estimate each skill's contribution to their teaching subjects. In this question, we used the Likert Scale mentioned above from 1 to 5, as shown in table 3.

Table 3. Likert Scale Used in the Survey

Likert Scale used in the Survey
One = Does not contribute
2 = Contributes little
3 = Sometimes Contributes
4 = Contributes
5 = Contributes a lot

From the statistical analysis done with the SPSS software, the closer the Mean is to 5, the higher the attribute evaluation (shown in table 4).

Table 4. Ranking of contributions of soft skills in design education

Skill	N	Min.	Max.	Mean	SD	Variance
Communication Skills	93	2	5	4.66	.667	.446
Critical thinking	93	2	5	4.65	.702	.492
Research and exploration	93	2	5	4.58	.727	.529
Creativity	93	2	5	4.54	.760	.577
Problem Solving	93	1	5	4.52	.816	.665
Curiosity	93	1	5	4.43	.914	.835
Decision Making	93	1	5	4.39	.794	.631
Open-mindedness	93	2	5	4.32	.810	.656
Systemic thinking	93	2	5	4.29	.879	.773
Empathy	93	1	5	4.28	.982	.964
Participation	93	2	5	4.26	.793	.628
Flexibility/adaptability	93	2	5	4.26	.779	.607
Collaboration	93	1	5	4.25	.928	.862
Learning to learn	93	1	5	4.18	1.042	1.086
Teamwork	93	1	5	4.15	.966	.934
Self-direction/ Self-management	93	2	5	4.05	.889	.791
Ethic/compromise	93	1	5	4.02	.944	.891
Judgement	93	1	5	3.69	1.063	1.130
Leadership	93	1	5	3.52	1.028	1.057
Entrepreneurship	92	1	5	3.27	1.178	1.387
Valid N (listwise)	92					

We also asked about the difficulty of evaluating soft skills, and 65% of teachers replied that they have difficulty assessing the learning of soft skills. The last closed question asked if teachers used any methodology that provided opportunities for teaching the skills mentioned in the survey. 80% said they did. An open-ended question finalised the questionnaire and asked the teacher to describe the methodology and/or practice (s)he uses to teach some of the soft skills mentioned in the questionnaire. We received Sixty-seven subjective answers. They were codified by identifying which central competence emerged. Professors explicitly cited some competencies; others appeared in between the discourse. For this analysis, we used the previously definitions to codify the skills.

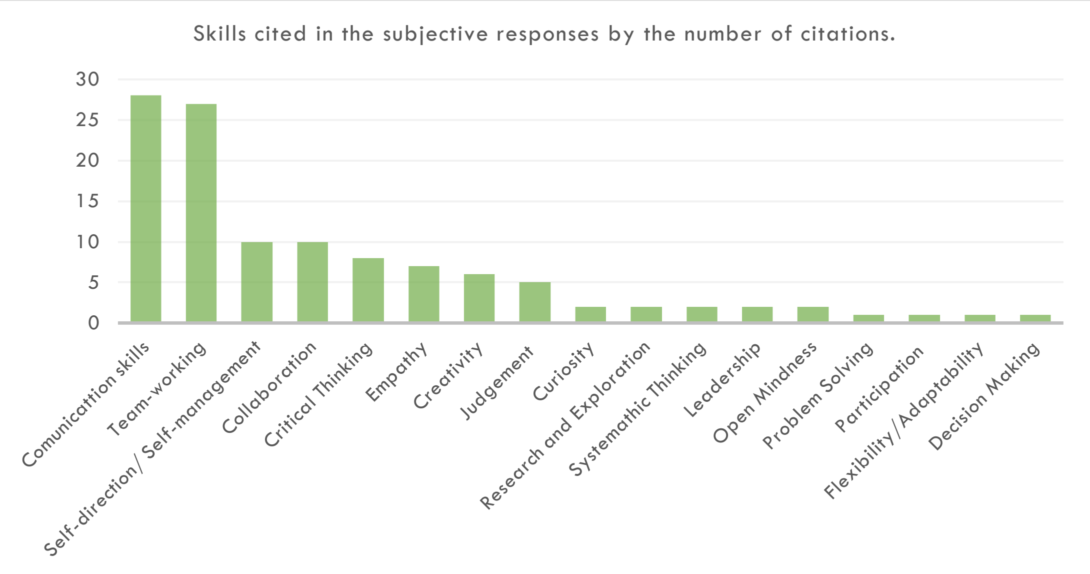


Figure 1. Skills cited in the subjective responses

Teachers' methods prevailed the learner-centred methods, active methods, group activities, self-evaluation/self-knowledge, and peer evaluation. They also cited the design thinking methods and activities focused on real-world problems. In this sense, some answers indicate applying a personality questionnaire and a survey of previous skills and more in-depth knowledge of the students' realities. There was also an indication of the need for non-standardisation of methods, adaptation to the student or class profiles, and individualisation of strategies.

What do the results say about the teaching of soft skills in design education?

The research results show that teachers ranked the soft skills with high rates for design practice. Among the 20 skills, none received an average ranking lower than 3. Only three skills received an average rating lower than 4 (Judging, Leadership and Entrepreneurship).

Regarding the skills that emerge as significant contributors to design courses, cognitive and individual skills (to the detriment of social and collective ones) appeared first and were rated the most important. Communication skills seem to be unanimous in the first place, as they also came first in the previous systematic review. Critical thinking, creativity, problem solving and curiosity appear between second and fifth place. It is essential to mention how some of the less widespread and discussed skills such as curiosity and open-mindedness ranked on average above more popular and widespread skills such as teamwork, empathy, collaboration, leadership and entrepreneurship.

Despite this, we identified an inconsistency in the teachers' discourse regarding teamwork competence, which appeared in the average ranking in 15th place but emerged in second place in the subjective answers.

The teaching practices identified by teachers as enabling the development of soft skills point to constructivist-based pedagogies, student-centred and active methodologies. Those practices mean, in our interpretation, a teaching approach more connected with reality and with methods that enable engagement, interaction with the group, self-assessments and peer evaluation.

To improve the systematisation of knowledge arising from this research, we propose a classification of competencies based on the literature review. This classification was created from the establishment of 2 sets: Skills performed mostly collectively versus skills performed mostly individually; we call this set collective/individual. The other classification was cognitive/metacognitive skills and interpersonal/social skills. In both groups, we also identified the need to create two sub-groups: The gateway competencies (Kaye & Giulioni, 2013) group and the high-order competencies group. The first group is composed of prior, initial skills necessary to develop more elaborate, complex skills.

Based on these four types of classification, we created a conceptual map to clarify the sets and the relationships identified between the skills in a visual way.

Relations between the competencies

The literature review carried out for the definition of the competencies revealed an interconnection between them. By analysing the delimitations, it was possible to establish links and associate them. The first link resulted from the analysis of the characterisation of curiosity, research and exploration, judgment, decision making, open-mindedness, creativity, flexibility, systematic thinking and critical thinking. Some authors demonstrate the sequential and conditional character of some of these competencies. (van Laar, et al., 2019; Bloom & Krathwohl,1956). It is possible to establish sets and, from these sets, realise that for the improvement of critical thinking competence, it is essential to have previously grown the other competencies mentioned above because the advance of critical thinking occurs or is made possible by developing previous skills. According to Siegel (2010), critical thinking enjoys a prominent status in contemporary educational goals and ideals and is considered a fundamental ideal and underlying objective of Western education. This status can explain why educators have widely mentioned this competence.

Researchers in the field have also discussed the relationship between creativity and critical thinking. According to Villalba (2011), critical thinking directly relates to creativity and is necessary for creativity to be realised.

> *(…) nowadays, it is generally accepted that creative thinking also entails convergent and critical thinking. While divergent thinking involves the generation of ideas, convergent thinking refers to the capacity to provide a*

> *single (or few) adequate idea(s). Creativity is usually associated with the capacity to produce something new and adequate. Divergent thinking would be needed to generate ideas, and convergent thinking would be used for choosing good ideas. Critical thinking can be considered as a part of convergent thinking. It involves the evaluation, analysis, synthesis, and interpretation of something to provide a judgment. Critical thinking thus provides the 'why' and 'how' of choosing one idea. In this sense, as creativity, it is always seen as a higher-order skill (Villalba, 2011, p.323).*

It is possible to establish the relationships between flexibility, a necessary competence for creativity, curiosity, and open-mindedness (OM); the latter one is a timely and valuable competence for divergent thinking. According to Lord (2015), from Socrates to contemporary education theorists, OM competence is essential for learning. More recent researchers argue that OM is critical to assessing the mental models of individuals, which are deeply held beliefs or conceptions that can confine them to familiar patterns of thinking and acting. It is also possible to establish the relationship between systematic thinking, creativity, and problem-solving, bearing in mind that systematic thinking is ultimately aimed at understanding problems. "Systemic thinking draws from diverse disciplines to provide a holistic method for dealing with issues in any field. It is scientifically grounded in systems theory and a wide variety of transdisciplinary supporting principles providing a discipline-agnostic approach to address messes" (Gallón, 2019, p.10).

The competence of research and exploration is also preceded by curiosity, defined for Kaye and Giulioni (2013) as a "Gateway Competency". An introductory competence, which induces others. Exploration and research, for example, derive from curiosity (Baxter & Switzky, 2008). The competence of research and the capacity to explore also seem to have this characteristic to lead to other competencies, such as trial, decision making and critical thinking. It isn't easy to separate these competencies objectively because they seem to be deeply intertwined one to the other. We can also establish the relationship between ethics and critical thinking if we think that the construction of ethical thinking involves rational thinking since the competence of Ethics is realised as a construction of a critically reflexive morality (Borstner & Gartner, 2014).

About the cognitive self-regulatory skills, learning to learn, and self-management skills are also related. Self-management involves the learning to learn competence, and both benefit from critical thinking, which is necessary for developing self-regulatory competence.

The competencies that we call Social/Interpersonal also maintain relationships with each other and with cognitive competencies. The need for critical thinking and ethics is unquestionable as "background" competencies for the optimal development of communication, empathy, teamworking, leadership, entrepreneurship, participation and collaboration skills. However, by analysing the definitions of these competencies more closely, it is possible to state that they appear to have greater independence from each other in their condition of practical realisation. This independence does not mean that the development of one competence does not favour the enhancement of another. Indeed, if the individual develops empathy competence, they will find it easier to grow leadership skills and work in groups. In this sense, it is possible to establish connections between Communication, Empathy, Collaboration, Participation and Team Working Skills. The ability to communicate well and develop listening skills can enhance Empathy skills. Consequently, being more empathetic makes it possible to be more inclined to the processes of collaboration and participation. Being able to communicate, listen, empathise and collaborate makes it possible to perform well in group work.

Finally, the skills that were assessed as less critical for design were leadership and entrepreneurship. These skills also benefit from the competencies mentioned above. It is expected that in the scope of contemporary design, which has a more collaborative character, leadership is a competence that has been assessed as less critical since the characteristic of collaboration is to be more horizontal and less hierarchical. Entrepreneurship also benefits from the competencies mentioned above; a designer with this type of competence can act not only in his own business but also in creating value, products and services for society in a broad sense. This value creation happens through private business or public services and social value, not driven by profit. Likely, the very definition present in the common sense of these competencies influenced this result. Although they came in the last place, the average rating of both was high at 3.54 and 3.46 respectively (out of a total of 5), which indicates an agreement on the contribution of these competencies to design of 70%.

Based on these reflections from the literature review, we create a conceptual map (figure 2) to understand the sets discussed here and some of their primary relationships in a visual way.

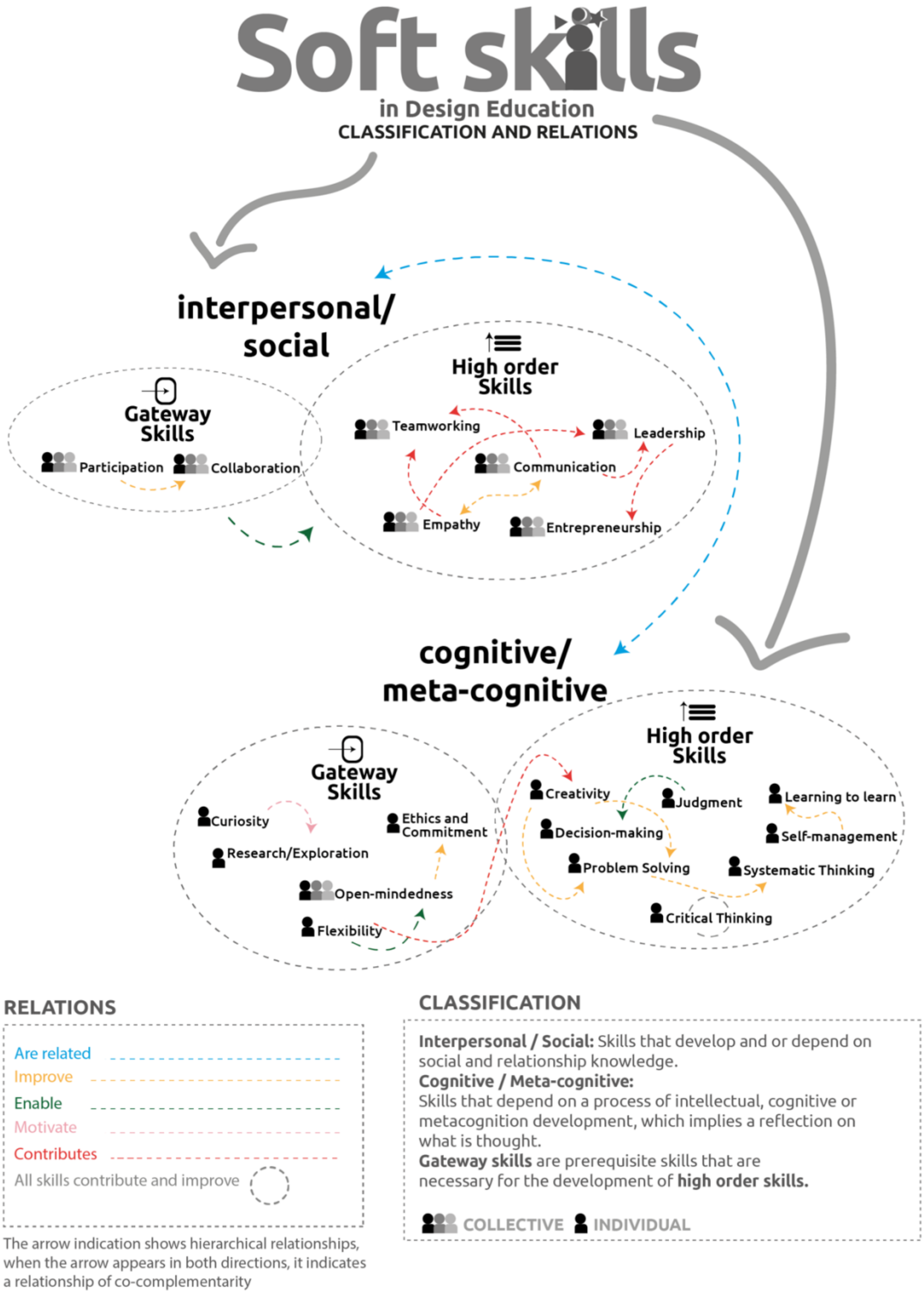


Figure 2. Concept Map: Soft skills in design education

Outlook

This research showed that the 20 soft skills identified in the systematic review have high importance for teachers in the areas where they work in design. It was possible to determine the relationship and interconnection between the soft skills and to suggest, from the literature review and through the analysis of subjective responses, an interdependence between them.

The proposed classification and the definition of the constructs projected in this article may make it easier for teachers and students to identify the primary soft skills in design education. It is possible to determine which soft skills should be enhanced as initial skills to develop high-performance skills. This classification can be the initial way to indicate which methods can be applied and how to evaluate these skills according to the student's formation level.

It is possible to develop teaching strategies to build the gateways skills in the initial years by creating activities that can gradually involve the students and increasingly require more skills to make them "scale up" the soft skills of the conceptual map.

Problem-based education is an efficient way of teaching soft skills (Crawford et al., 2020) and is already widely developed in many design schools. It can be extended to teach soft skills in a more structured way and make it possible to evaluate them. This teaching approach should take place simultaneously with the development of traditional design skills (hard skills). According to the literature on teaching and learning soft skills, the following conditions must be met to achieve this goal:

- Contextualised teaching (Frascara, 2018)
- Increased contact with complex problems (Ringvold & Digranes, 2017; Azim et al., 2010)
- Active methodologies and a student-centred learning approach; (Leong et al., 2018)
- Integration between areas (interdisciplinarity between course subjects, but necessarily between diverse courses that coexist on campus or in the community); (OECD, 2018)

The study can also be applied to analyse and evaluate students' competencies and establish each student's profile. Thus, potentiating their learning, enabling a more individual and affective pedagogy. It means a pedagogy that looks to students with personal attention, considering their subjectivism and reality.

The use of constructs can be the beginning of a more objective evaluation of these skills within the teaching of design, allowing later the creation of indicators for assessing skills. In the same way, students can carry out a self-evaluation and observe their skills more critically from this map and the constructs.

Future studies should be carried out to verify the perception of these skills in the students and how they learn and enhance these skills. It is also necessary to know how practitioners consider this subject and assess the importance and level of these skills to design students entering the labour market.

Finally, it is interesting to raise the issue of design approaches and the development of these skills. Possibly some methods can enhance and be more complex learning environments than others in design education. The more complex, anchored in real-world problems and involving more relationships between communities and between professionals and different areas, the more these skills can be developed. Therefore, approaches to design that make it possible to face the complexity of wicked problems, of the turbulent relationships that arise within a designer's actual work, are more conducive to developing these skills.

Boundaries of the study

This study is part of an ongoing PhD research aiming to identify and validate the importance of 20 soft skills for design education. Although we intended to take a global view, we focused on participants from Brazil and Portugal. It was not possible to expand the sample size due to established time limits to the progress of the research, which, if extrapolated, would imply significant delays for the thesis. Moreover, as this is part of a more extensive study, it was impossible to include the students' views of these soft skills in the survey.

Nevertheless, we have already done other studies with students in which we involve students in a co-creation of strategies to teach and learn soft skills in design education (cf. Freitas & Almedra, 2021).

Acknowledgements

This work was financially supported by the Research Centre for Architecture, Urbanism and Design (CIAUD) at the Faculty of Architecture, University of Lisbon (FA/ULisboa), Portugal, and also by the State University of Pará (UEPA), Brazil.

References

Azim, S., Gale, A., Lawlor-Wright, T., Kirkham, R., Khan, A., & Alam, M. (2010). The importance of soft skills in complex projects. International Journal of Managing Projects in Business, 3(3), 387–401. https://doi.org/10.1108/17538371011056048

Baxter, A., & Switzky, H. N. (2008). Exploration and Curiosity. In Encyclopedia of Infant and Early Childhood Development (Vol. 1–3, pp. 460–470). Elsevier. https://doi.org/10.1016/B978-012370877-9.00058-X

Bloom, B. S. (1956). Taxonomy of Educational Objectives: The Classification of Educational Goals. Handbook I: Cognitive Domain.

Borstner, B., & Gartner, S. (2014). Teaching ethics and critical thinking in contemporary schools. Problems of Education in the 21st century, 61, 9–17.

Cambridge Dictionary. (2020). Participation. In Cambridge Dictionary. Retrieved from dictionary.cambridge.org/pt/dicionario/ingles/participation

Cambridge Dictionary. (2020). Judgment. Retrieved from dictionary.cambridge.org/pt/dicionario/ingles/judgment

Cegarra-Navarro, J. G., & Cepeda-Carrión, G. (2008). Why Open-mindedness Needs Time to Explore and Exploit Knowledge. Time & Society, 17(2–3), 195–213. https://doi.org/10.1177/0961463X08093422

Chicago State University. (2013). Problem Solving. Retrieved from https://www.csu.edu/humanresources/empdev/documents/ProblemSolving.pdf

Crawford, A., Weber, M. R., & Lee, J. H. (2020). Using a grounded theory approach to understand the process of teaching soft skills on the job so to apply it in the hospitality classroom. Journal of Hospitality, Leisure, Sport and Tourism Education, 26(January), 100239. https://doi.org/10.1016/j.jhlste.2020.100239

Davis, M. (2017). Teaching Design: A guide to Curriculum and Pedagogy for College Design Faculty and Teachers who use design in Their classrooms. New York: Allworth Press.

England, T. K., Nagel, G. L., & Salter, S. P. (2020). Using collaborative learning to develop students' soft skills. Journal of Education for Business, 95(2), 106–114. https://doi.org/10.1080/08832323.2019.1599797

European Council. (2006). Recommendation of the European Parliament and the Council on key competencies for lifelong learning. Official Journal of the European Union, (March 2002), 10–18. Retrieved from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:394:0010:0018:en:PDF

Findeli, A. (2001). Rethinking Design Education for the 21st Century: Theoretical, Methodological, and Ethical Discussion. Europian Journal of Arts Education, 17(1), 5–18.

Frascara, J. (2018). Enseñando diseño. Buenos Aires: Infinito.

Freire, P. (1997). Pedagogia da Autonomia: Saberes necessários à prática educativa. São Paulo: Editora Paz e Terra.

Freitas, A. P. N., & Almendra, R. A. (2021). What if…? Strategies to Teaching Communication, Empathy and Teamworking for Design Students by Design Students. In C. S. Shin, G. Di Bucchianico, S. Fukuda, G. Yong-Gyun, G. Montagna, & C. Carvalho (Eds.), Advances in Industrial Design (pp. 148–156). Cham: Springer International Publishing.

Freitas, A. P. N., & Almendra, R. A. (in press.). Teaching and Learning Soft Skills in Design Education, Opportunities and Challenges: A Literature Review. In E. Duarte & C. Rosa (Eds.), Developments in Design Research and Practice: Best papers from 10th Senses and Sensibility 2019: Lost in (G) Localization. Lisbon: Springer International Publishing.

Frey, B. B. (2018). The SAGE Encyclopedia of Educational Research, Measurement, and Evaluation. Active Learning: Social Justice Education and Participatory Action Research. 2455 Teller Road, Thousand Oaks, California 91320: SAGE Publications, Inc. https://doi.org/10.4135/9781506326139

Friedman, K. (2012). Models of Design: Envisioning a Future Design Education. Visible Language, 46, 132–153.

Gallón, L. (2019). Systemic Thinking. In W. Leal Filho, A. M. Azul, L. Brandli, P. G. Özuyar, & T. Wall (Eds.), Quality Education (pp. 1–11). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-69902-8_58-1

Harari, Y. N. (2018). 21 Lessons for the 21st Century - Yuval Noah Harari. Jonathan Cape.

Haselberger, D., Oberhuemer, P., Perez, E., Cinque, M., & Capasso, F. (2010). Mediating Soft Skills at Higher Education Institutions.

Kaya, F. (2020). Flexibility. In Encyclopedia of Creativity (pp. 505–509). Elsevier. https://doi.org/10.1016/B978-0-12-809324-5.23597-9

Kaye, B., & Giulioni, J. W. (2013). Curiosity: The Gateway Competency. Retrieved June 6, 2020, from https://www.chieflearningofficer.com/2013/01/18/curiosity-the-gateway-competency/

Kember, D., & Leung, D. Y. P. (2005). The influence of active learning experiences on the development of graduate capabilities. Studies in Higher Education, 30(2), 155–170. https://doi.org/10.1080/03075070500043127

Leong, L. C., Hassan, N., Isa, F. M., & Ab Jalil, H. (2018). Mobile X-Space design, teaching strategies and undergraduate students' collaborative learning behaviour: A case study in Taylor'S University, Malaysia. Malaysian Journal of Learning and Instruction, 15(2), 175–205.

Majid, S., Liming, Z., Tong, S., & Raihana, S. (2012). Importance of Soft Skills for Education and Career Success. International Journal for Cross-Disciplinary Subjects in Education, 2(Special 2), 1036–1042. https://doi.org/10.20533/ijcdse.2042.6364.2012.0147

Menzel, D. C. (2016). Ethical Competence. In Global Encyclopedia of Public Administration, Public Policy, and Governance (pp. 1–4). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-31816-5_2458-1

Meyer, M. W., & Norman, D. (2020). Changing Design Education for the 21st century. She Ji: The Journal of Design, Economics, and Innovation, 6(February), 13–49. https://doi.org/10.1016/j.sheji.2019.12.002

Moran, J. (2015). Mudando a educação com metodologias ativas. Convergências Midiáticas, Educação e Cidadania: Aproximações Jovens. Retrieved from www2.eca.usp.br/moran/wp-content/uploads/2013/12/mudando_moran.pdf

Moran, J. M. (2018). Metodologia ativas para uma aprendizagem mais profunda. Metodologias ativas para uma educação inovadora: uma abordagem teórico-prática. Porto Alegre: Penso.

Mumford, M. D., & Gujar, Y. (2020). Leadership. In Encyclopedia of Creativity (Vol. 2, pp. 33–38). Elsevier. https://doi.org/10.1016/B978-0-12-809324-5.23679-1

Norman, D. (2010). Why Design Education Must Change. Retrieved January 22, 2019, from https://jnd.org/why_design_education_must_change/

Organization for Economic Co-operation and Development. (2009). Higher Education to 2030. OECD. https://doi.org/10.1787/9789264075375-en

Organization for Economic Co-operation and Development. (2005). The definition and selection of key competencies. OECD. Paris.

Organization for Economic Co-operation and Development. (2018). The Future of Education and Skills: Education 2030. OECD Education Working Papers. Paris. https://doi.org/10.1111/j.1440-1827.2012.02814.x

Parker, A. M., Bruine de Bruin, W., Fischhoff, B., & Weller, J. (2018). Robustness of Decision-Making Competence: Evidence from Two Measures and an 11-Year Longitudinal Study. Journal of Behavioral Decision Making, 31(3), 380–391. https://doi.org/10.1002/bdm.2059

Parthasarathy, N., Doboli, S., & Paulus, B. (2011). Entrepreneurship. In M. A. Runco & S. R. Pritzker (Eds.), Encyclopedia of Creativity - Second Edition (pp. 461–467). San Francisco: Elsevier.

Paul, R., & Elder, L. (2007). Critical Thinking Competency Standards. Foundation for Critical Thinking Press. Retrieved from https://curriculum.gov.bc.ca/sites/curriculum.gov.bc.ca/files/pdf/CriticalThinkingCompetencyProfiles.pdf

Prokhorchuk, A. (2014). The definition of “ research competence .” Edukacja - Technika - Informatyka, V(1), 439–443.

Ringvold, T. A., & Digranes, I. (2017). Future scenarios in general design education and 21St century competencies. Proceedings of the 19th International Conference on Engineering and Product Design Education: Building Community: Design Education for a Sustainable Future, E and PDE 2017, (September), 98–103. Retrieved from https://www.scopus.com/inward/record.uri?eid=2-s2.0-85042134262&partnerID=40&md5=aa4bc6c337d2a8ffc394fbb3dc2fc95d

Rychen, D. S. (2016). Education 2030: Key competencies for the future. Retrieved from http://www.oecd.org/education/2030/E2030-CONCEPTUAL-FRAMEWORK-KEY-COMPETENCIES-FOR-2030.pdf

Rychen, D. S., & Salganik, L. H. (2003). Key competencies for a successful life and a well-functioning society. Key competencies for a successful life and a well-functioning society.

Salas, E., & Cannon-Bowers, J. A. (2001). Teamwork and Team Training. In International Encyclopedia of the Social & Behavioral Sciences (pp. 15487–15492). Elsevier. https://doi.org/10.1016/B0-08-043076-7/01436-4

Siegel, H. (2010). Critical Thinking. In International Encyclopedia of Education (pp. 141–145). Elsevier. https://doi.org/10.1016/B978-0-08-044894-7.00582-0

Spitz, R. (2021). Designing design education: Whitebook on the future of design education. Hanover: If Design Foundation.

Succi, C., & Canovi, M. (2020). Soft skills to enhance graduate employability: comparing students and employers' perceptions. Studies in Higher Education, 45(9), 1834–1847. https://doi.org/10.1080/03075079.2019.1585420

Transforming Education. (2014). Introduction to Self-Management. Retrieved from https://www.transformingeducation.org/wp-content/uploads/2019/04/Introduction_to_Self-Management_Handout_Final_CC.pdf

van Dijk, J. A. G. M., & van Deursen, A. J. A. M. (2014). Digital Skills. New York: Palgrave Macmillan US. https://doi.org/10.1057/9781137437037

van Laar, E., van Deursen, A., & van Dijk, J., & de Haan, J. (2019). The Sequential and Conditional Nature of 21st-Century Digital Skills. International Journal of Communication, 13. Retrieved from https://ijoc.org/index.php/ijoc/article/view/10925/2731

Villalba, E. (2011). Critical Thinking. In Encyclopedia of Creativity (2nd ed., pp. 323–325). Elsevier. https://doi.org/10.1016/B978-0-12-375038-9.00057-1

Virtanen, A., & Tynjälä, P. (2018). Factors explaining the learning of generic skills: a study of university students' experiences. Teaching in Higher Education, 2517. https://doi.org/10.1080/13562517.2018.1515195

Ward, T. B. (2004). Cognition, creativity, and entrepreneurship. Journal of Business Venturing, 19(2), 173–188. https://doi.org/10.1016/S0883-9026(03)00005-3

World Health Organization. (1994). Programme on Mental Health: Life Skills in Schools. WHO World Health Organization. Geneva.

Which visualisation tools and why? Evaluating perceptions of student and practicing designers toward Digital Sketching

Dr. Charlie Ranscombe, Swinburne University of Technology, Australia
Dr. Wendy Zhang, University of Canterbury, New Zealand
A/Prof. Boris Eisenbart, Swinburne University of Technology, Australia
Prof. Blair Kuys, Swinburne University of Technology, Australia

Abstract
An ever-increasing array of design visualisation tools are available to designers. As such, design education is constantly challenged to keep up with these trends so that students are best equipped for entering industrial practice. This paper reports a study into the use of digital sketching, a relatively new digital visualisation tool. The study aims to identify thematic differences in how students and practitioners perceive digital sketching. These are given in terms of the tool's characteristics, and how these characteristics guide its application in early stages of the design process. Data on perceptions is captured using design diaries and semi-structured interviews. Results show key differences in the way that practitioners perceive the intent of visualisation. Practitioners focus on iterating towards a solution during the design process. Students are much more focused on the task of creating visualisations. This reveals an underlying contradiction in the way tools are perceived between creating visualisations to gain expertise or skill, versus creating them to advance the design process. The insights help improve our understanding of how the different characteristics of digital sketching inform its use. We reflect on how we educate students with respect to selecting and using digital sketching. We conclude with implications for education of digital sketching, as well as other emerging digital visualisation tools.

Keywords
Digital Sketching, Emerging Technologies, Visualisation, Prototyping, Design Education, Fidelity

Introduction
There is a wide array of visualisation tools available to designers in industrial and engineering design disciplines. More and more variations of sketching, 3D modelling, physical and non-physical prototyping, as well as virtual and augmented reality (VR/AR) applications are becoming commonplace (Zhang, Ranscombe, Radcliffe, & Jackson, 2019). As computing technology advances at an ever-rapid pace, so too does the capability and breadth of applications for digital visualisation tools in the design process. By extension, design educators are faced with the challenge of choosing the most appropriate technologies in which to educate students (Abouelala, Janan, & Brandt-Pomares, 2015). These be meaningful for years to come and effective in helping students create the outcomes of the future. At the same time, students also need to be educated on how the choice of tools can markedly influence the design process and its outcomes (Brisco, Whitfield, & Grierson, 2020).

Well established visualisation tools such as traditional sketching and CAD have been studied as to how their characteristics can influence designers' thinking and hence their optimal use during the design process (Lawson, 2002; J. A. Self, 2013; Tsai & Yang, 2017). From the perspective of design education these tools have also been researched with a major trend highlighting that students have a preference to use more high-tech tools that characteristically offer visualisations with greater levels of detail and realism (Ranscombe, Bissett-Johnson, Mathias, Eisenbart, & Hicks, 2020; Thurlow & Ford, 2017). In turn, the selection of higher fidelity digital visualisation tools (e.g., 3D modelling and rendering) over lower fidelity tools, such as sketching, leads to corresponding negative impacts. These include bounded ideation and an unwillingness to iterate (Robertson & Radcliffe, 2009; Thurlow & Ford, 2017; van Passel & Eggink, 2013). Conversely an indicator of more experienced designers is being adept at applying a range of tools to traverse a wide range of ideas (idea fluency) more effectively, iterating towards highly developed solutions (Crismond & Adams, 2012; J. Self, Dalke, & Evans, 2009)

Given the trend in students' preference for high-tech tools discussed above, and the unrelenting advances and sophistication in digital visualisation tools becoming available, there is a need to research the perceptions of students towards selection and use of digital visualisation tools within the design process. At the same time, given experienced designers are more adept at tool selection, there is also value in capturing their perceptions of tools to reflect against student perceptions. The visualisation tool this paper focuses on is digital sketching, an example of a relatively new/emerging visualisation tool. The specific research aim is to identify thematic differences in how students and practitioners perceive digital sketching in terms of the tool's characteristics, and how these characteristics guide its application in early stages of the design process. In doing so, we aim to provide insights on how we educate students with respect to selecting and using digital sketching and, by extension, other emerging visualisation tools. The following section gives a background to digital visualisation tools in design education and explains our approaches to characterise design tools.

Background

As a background to this study, we will first summarise the extant literature on the topic of digital visualisation tools in design education. This provides a basis for the study and the subsequent review of the different characteristics of visualisation tools.

Digital visualisation tools in Higher Education

As stated in the previous section, a body of research exists exploring the role of visualisation tools within the design process, including student use (or lack of) different tools. Traditional sketching is routinely flagged as a critical visualisation tool for designers, as a means to embody ideas as well as communicate them to others (Goldschmidt, 1991; Lawson, 2006). Speed, opportunity for reflection and reinterpretation as the designs emerge on the page are cited as key reasons for its use. Yet, research in design education shows that despite these positive characteristics, inhibition to share and communicate with sketches mean students often do not engage easily with this tool (Thurlow & Ford, 2017; van Passel & Eggink, 2013). Instead, students have a preference for more advanced digital visualisation tools that offer greater resolution and visual aesthetic (Ranscombe et al., 2020). Scholars have linked these tools to negative impact on; creativity (bounded ideation), breadth of ideas explored, and willingness to iterate possible solutions (Robertson & Radcliffe, 2009; Thurlow & Ford, 2017). Conversely researchers have also identified a marker of experienced designers is their capacity to select different tools based on their suitability to different design activities and goals (Crismond & Adams, 2012; J. Self et al., 2009). This final point should be noted as it supports the practice of educators to refer to those in industry to outline which visualisation tools should be included in design curricula.

Among the breadth of new visualisation tools referred to in the Introduction is digital sketching. For the purpose of this paper, we define digital sketching as a visualisation tool that affords drawing (usually with pen/stylus-based input) in 2D digital design software (See example in Figure 1). Recent decrease in costs of digital sketching hardware, increased computational power, and integration of sketch input within some 3D modelling software has seen its use rise in industry and cemented its presence in design education. Recent research into digital sketching suggests it embodies a form of hybrid visualisation tool. It offers some of the complementary characteristics of traditional sketching (speed and reinterpretation) and CAD (detail and aesthetics), hence mitigating some of the issues highlighted above (Ranscombe, Zhang, Rodda, & Mathias, 2019). Thus, digital sketching is the focus of this paper as we contend it is an example of a relatively new or emerging type of digital visualisation tool. As such, we seek to inform design education's approach to incorporating this design tool in design education.

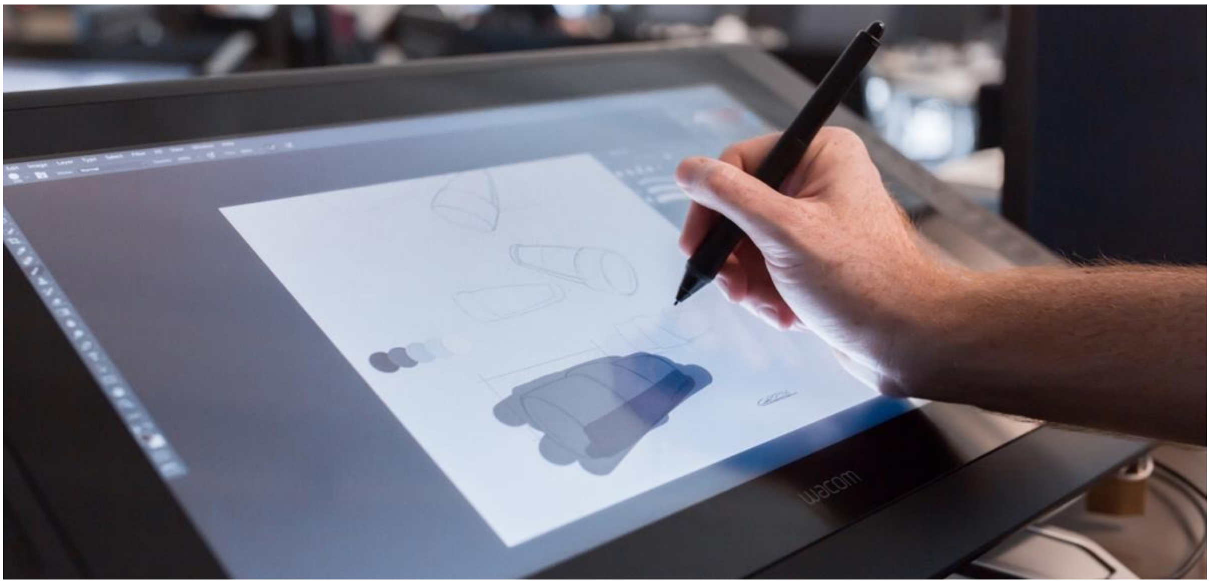


Figure 1. Example of a digital sketch created using a digital tablet and stylus (Author's own)

Characterising design tools

Extant literature on design processes (Purcell & Gero, 1998), visualisation (Pei, Campbell, & Evans, 2011; J. Self et al., 2009), prototyping (Camburn et al., 2017; Mathias, Hicks, Snider, & Ranscombe, 2018) and collaborative design (Brisco et al., 2020) offer various frameworks to study design tools and their applications by classifying their characteristic benefits and limitations. While digital sketching is the focus of our study, the purpose is to provide insights on tool use that can be generalised beyond digital sketching to the study of other emerging tools. To do so, we require a means to characterise design tools in a generalised way. The frameworks referenced above illustrate the utility of design tool characteristics as a basis to analyse design visualisation tools in the industrial design field. Furthermore, a number of frameworks have been employed to research designers' use of tools (M. Evans & Aldoy, 2016; Jonson, 2005; Lutters, Van Houten, Bernard, Mermoz, & Schutte, 2014; Robertson & Radcliffe, 2009), setting a precedent for researching tool characteristics as a way to inform best practice. Existing frameworks to classify the use of design tools also provide different perspectives on investigating the design tool characteristics. These include both the tools' capabilities and those of the users' applying the tools. However, existing highly cited frameworks (Pei et al., 2011; J. Self et al., 2009) comprise a relatively limited number of characteristics, which may put constraints on conducting in-depth investigations of different tools. Similarly, the individual frameworks usually focus on a particular tool or perspective such as affordances of tools. Alternately they are without the context of the user's capability, limiting the applications of the framework in broader contexts.

More recently, Zhang et al. (2019) synthesised the literature to present an exhaustive framework of generalised design tool characteristics, which is used as the basis to compare even substantially different tools (sketching and CAD) (Zhang, 2020). The Design Tool Characteristics (DTC) framework combines the perspectives of both the affordances of the design tools and designers' tool-use behaviours and activities. The DTC framework also offers a more comprehensive list of universal design tool characteristics, providing a foundation to understand various design tools at different stages during the industrial design process. Moreover, the DTC framework's comprehensiveness enables comparing the design tools from a multifaceted view. This is because associations between characteristics can be captured in addition to individual characteristics if desired. Hence, for these reasons it is adopted in this study as the best means to understand perceptions in terms of design tool characteristics, and in a generalised manner (See Table 4 for a summary of the framework).

Method

The method used to evaluate student and practitioner perceptions of digital sketching in terms of the tool's characteristics is now described. Participants in this study are first outlined, then details of the diary and semi-structured interview methods adopted are explained. This is followed by an explanation of coding to highlight themes in perceptions from the two groups studied, explaining how referencing of design tool characteristics forms the basis for comparing perceptions of digital sketching.

Participants

Student perceptions were gathered as part of a visualisation course taught to postgraduate students undertaking a Masters of Design degree at Swinburne University of Technology. A total of 69 students were sampled over 2 consecutive years of delivering the same design project within the same design visualisation course (2017 and 2018). Perceptions were captured in the context of a 7-week design/visualisation project where the objective was to create concepts for a household appliance (a pod coffee machine). This project was selected as the basis for analysis as it reflects a typical design activity (i.e., ideation and concept design) in which digital sketching is used. Students were expected to use digital sketching throughout the project but had the choice to use 3D modelling software towards the end of the project.

For our practitioner sample, eleven practitioners from three engineering and design consultancies in Melbourne, Australia were interviewed during May and June 2018.

Consultancies were targeted as such practitioners would likely have worked on a wide range of products during their tenure. In-house design teams were avoided as they would likely only have experience with a certain product category. The sample of eleven participants captured a range of experience levels from junior designers to design/project managers (further details shown in Table 1).

Table 1. Details of practitioners interviewed

Participant	Experience (Years)	Company	Role
P1	>5	1	Project Leader
P2	≤5	1	Designer
P3	>5	2	Designer
P4	>5	3	Designer
P5	>5	1	Manager
P6	>5	2	Project Leader
P7	>5	1	Designer
P8	≤5	1	Designer
P9	≤5	1	Designer
P10	≤5	1	Designer
P11	>5	3	Manager

Instruments: Student diaries and practitioner interview structure

Student perceptions were collected using a diary method as used in comparable studies (Badke-Schaub & Frankenberger, 1999; M. A. Evans, Pei, Cheshire, & Graham, 2015; Pedgley, 2007). The diary method was selected on the basis that it facilitates capturing data for a large number of students at various points throughout their design process. Diary entries were recorded by students as part of a design project portfolio that students submitted at the end of the project. Diary entries were made on a standardised template throughout the project at weekly intervals over the duration of the project. They were submitted as part of their design project portfolio at the end of the course. Within each entry, students were prompted to reflect in up to 100 words on the use of digital sketching to visualise and develop or modify their ideas. Specifically, students were given the following two prompts to answer in each diary entry; "How did you find digital sketching to visualise ideas?", and "How did you find digital sketching to develop or modify your ideas?" These prompts were designed to reflect the way in which designs are initially conceived but also developed over the course of a design project. Prior to analysis, diaries were screened for intelligibility and relevance to the study. Of the 69 students recruited, 7 student diaries were excluded from analysis due to multiple blank or nonsensical entries. The remaining 62 diaries were transcribed and transferred to an NVivo database for coding.

Data collection for practitioners was carried out with careful consideration for intellectual property and time constraints of those involved. As a consequence, it was not possible to acquire equivalent diary entries embedded within a project portfolio from practitioners. As an alternative, a semi structured interview method was adopted. The rationale for using interviews was to capture perceptions and lived experiences of designers' use of the tool within design projects without disclosing intellectual property. Second, it facilitated further questioning and context building by the interviewer providing rich data. A controlled experiment in which all participating designers work on the same task was avoided as such an experiment would take the designers out of their natural or preferred practices. Likewise, although a standardised task would aid comparison, it would also mean key findings are potentially only relevant to the task at hand.

Each interview lasted approximately 60 mins (45mins being the shortest and 89mins being the longest). The interview followed the structure set out in Table 2. These prompts were designed to cover the same topics as students' diaries (visualisation and modification of emergent designs), while giving flexibility to pose further questions. Participants were asked to base their responses to questions on recent design projects that they felt were representative of their typical design activities.

Table 2. Semi-structured interview prompts

Prompt	Theme
What tool and representation do you prefer to visualise your ideas in the early design phase? Why?	Visualising
Are the design tools quick enough to catch up with your creative flow during the design process?	Visualising
Do you find Digital Sketching easy and effective for moving between design ideas (different solutions)?	Visualising & modifying
Is it easy to make changes to ideas using Digital Sketching?	Modifying
Do you find Digital Sketching helpful for developing details and variations of one/the same design idea?	Modifying
(Follow-up Question): Do you think it is more related to the tool itself or your expertise/skills regarding this answer?	

Primary Data Coding

The design tool characteristics framework by Zhang et al. (2019) is adopted as the basis to code diaries and interviews. Due to the different form of data collected between students (diary) and practitioners (interview), a two-staged approach to analysis was adopted. First, a high-level coding was conducted using the same scheme to analyse both student and practitioner data sets. This formed the basis to draw out themes in students' and practitioners' perceptions. Primary coding was conducted using a scheme based on Zhang et al. (2019), but where characteristics are grouped into higher level themes (see Table 3 for definitions of each theme and Table 4 for how design tool characteristics are grouped into themes). The number of references to each code/theme was counted, and relative proportion of themes coded with respect to the total data set is given.

Secondary Coding for further analysis of practitioner data

Practitioner interviews were coded a second time using the full DTC framework (Zhang et al. 2019) describing higher-level themes in more detail in terms of specific DTCs. Table 4 sets out the secondary coding scheme outlining how specific characteristics relate to themes coded in the primary coding stage. As such the richer coding forms the basis to explain similarities and differences between students and practitioners. It also forms the basis to discuss implications for design education with respect to how the best applications of digital visualisation tools are taught in design education. Practitioner interview transcripts are coded in the same manner as in the primary coding with data is presented proportionally. This facilitates high level evaluation of similarities and differences between students and practitioners.

Table 3. Definitions used in the high-level coding scheme

High - Level Themes	Communication	Design Thinking	Representation	Time	Usability
Definition	References to the tools' capacity to communicate emergent designs. This includes communication with others but also the concept of "Dialogue with Self" (Goldschmidt, 1991), referring to the externalisation of an emergent design to support a self-reflective activity	References to designerly ways of thinking. Statements that relate to cognitive activity that typically occurs alongside visualisation activities. Includes statements that reference concepts such as problem reframing and lateral and vertical transformations to a design.	References to the resulting qualities of visualisations. This category represents the manifestation of visualisation rather than any activity (cognitive or physical) by the designer to create the visualisation.	References to the time involved in creating visualisations. This includes reference to the use of visualisation media but also the time taken to learn how to use a given media.	References to usability, and considerations associated with creating visualisation media.

Table 4. Design Tool Characteristics used to further code practitioner interviews

High Level Themes	Communication	Design Thinking	Representation	Time	Usability
Framework of Visualisation Tool Characteristics (Zhang et al., 2019)	External Communication	Lateral Transformation	Accuracy	Learning Cost	Compatibility
	Internal Communication	Problem Re-Framing	Ambiguity	Use Cost	Flexibility
		Vertical Transformation	Amount of Representation		Immediacy
			Fidelity		Mobility
			Holistic View of Objects		
			Level of Aesthetics		
			Level of Details		

Results

First, data from primary coding is presented for evaluation of thematic differences in how students and practitioners perceive digital sketching. Next, results from secondary coding of practitioner data are given to provide richer understanding of designer perceptions with respect to characteristics that guide their use of digital sketching. A discussion of the differences and explanation of findings is subsequently given in the discussion section.

Student and practitioner perceptions of digital sketching

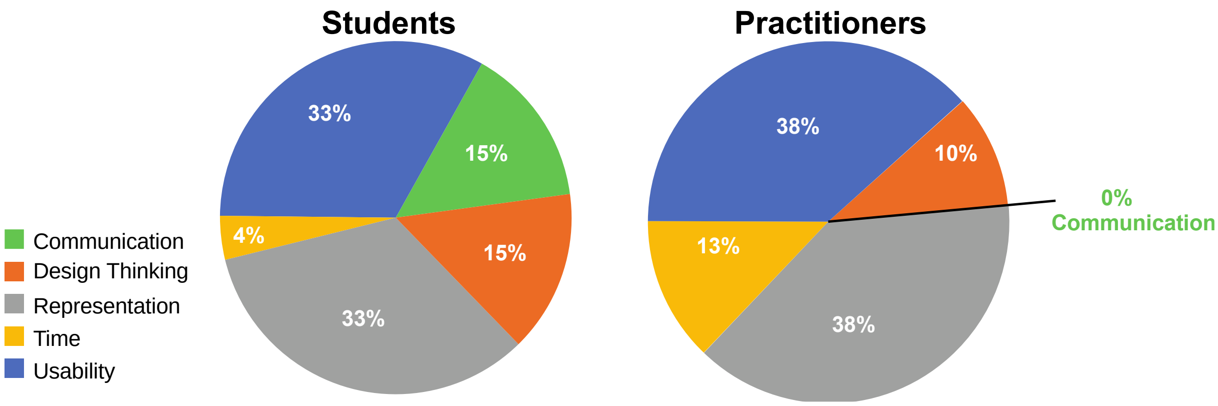


Figure 2. Overview of high level themes referenced by students and practitioners

The greatest contrast between student and practitioner perspectives is that practitioners make no reference to using visualisations to communicate (i.e. zero references under the communication theme). We contend this is partially explained by some diary entries explicitly referencing the way students use their visualisations to seek feedback from teaching staff or classmates. For example, “After consulting with the tutor, the form was recreated with curved edges” and “draw them and express them in front of others” and “problem to introduce them through Maya software”. In comparison, practitioners do not explicitly describe the use of visualisations to communicate with others when developing their own ideas. Likewise (as explained in 3.1) practitioner responses that relate to visualisation with a client or external stakeholder were excluded from the comparison. It is noted that the communication category does include “dialogue with self” which would not be excluded. The lack of this kind of reference is discussed in following section.

The next biggest difference between data sets is in referencing of the time theme, 4% by Students and 11% Practitioners. While the proportion of references is relatively low, the comparative difference is almost threefold. Further discussion of this difference is given in the following section.

Evaluating the themes in student and practitioner perceptions, there is similarity in their frequent referencing of representation and usability themes. The relatively large proportion of references to the representation theme (approximately one-third of responses) is perhaps not surprising. It could be argued that the primary objective of any design visualisation is to represent potential ideas. Thus, it is expected that characteristics relating to this objective (or that describe the manifestation of visualisation) feature heavily in responses of both groups.

Finally, we note there is a small difference in the proportion of references to the design thinking theme by both student and practitioner data sets (15% and 9% respectively). As with the communication theme, it is a relatively low level of referencing by both groups. We contend this stems from digital sketching being used to “design”, and therefore its connection to design thinking is implied but not explicitly expressed.

Further coding of practitioner interviews

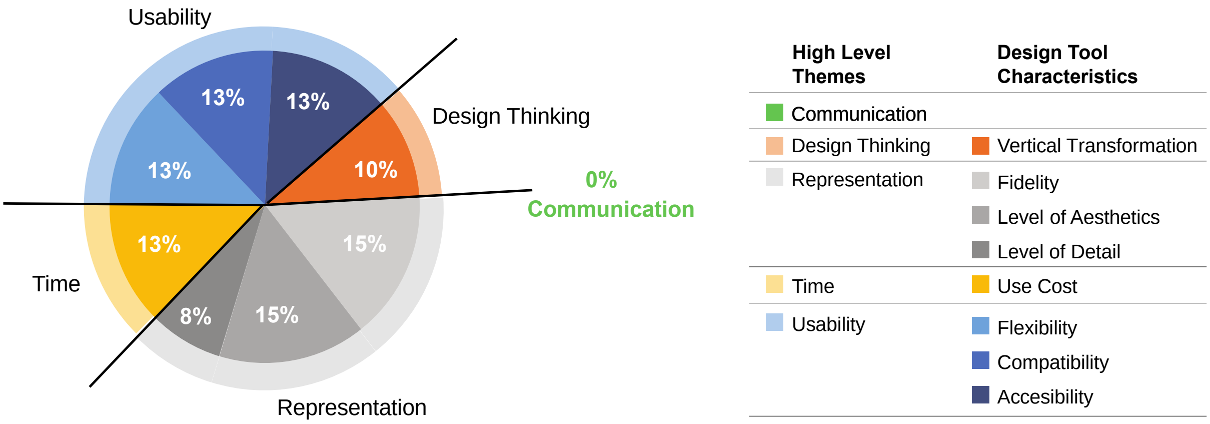


Figure 3. Illustrating design tool characteristics referenced by practitioners within high level themes described in primary coding

With respect to practitioner’s views on usability, we can see this theme is described equally in terms of flexibility, accessibility and compatibility. We contend accessibility and compatibility are referring to “logistical” aspects of digital sketching meaning the access to equipment and compatibility of visualisation with other design tools. Flexibility, however, is further from pure logistics, as it describes the flexibility to iterate or change designs. In other words, characteristics within the usability theme extend beyond pure usability of the tool, but also consider usability from the perspective of executing an iterative design process.

With respect to the representation theme, practitioners refer to fidelity of the representation and level of aesthetics in equal proportion. They describe level of detail less frequently. Associated with fidelity and level of detail is the single characteristic cited with respect to the design thinking theme, vertical transformation. When talking on the theme of representation, designers exclusively refer to the tool's capacity for iterating and developing designs in terms of adding detail. This is opposed to lateral transformation (See Table 2) which is not mentioned, defined as ideating a range of ideas. Likewise, use cost is the only time related characteristic mentioned. Learning cost (time and effort expended to learn the tool) is not mentioned, although this is likely because questions did not cover practitioners' learning experience of digital sketching. In summary, as with the range of characteristics cited in the usability theme, practitioners are motivated by characteristics that support iterative development of ideas.

Discussion

Referring to Section 4.1, the starkest differences in themes referenced by the two groups are with respect to communication and time themes. As discussed above, the difference in references to the communication theme is likely influenced by the methodology. Nevertheless, it is worth noting instances where students reference communication (seeking feedback from teaching staff or classmates) align with the external communication characteristic only. That is to say, no students made any references that point to the use of visualisation as a means of self-reflection; "dialogue with self"(Goldschmidt, 1991). This is consistent with practitioner data where this theme also did not arise. It is possible that such a view of sketching/visualisation is very theoretical, and hence not something that either students or practitioners would explicitly state.

Aside from communication, we contend referencing the time theme is most interesting in terms of differences in perceptions. References by practitioners to the time theme are largely associated with time investment to iterate and develop ideas towards a final product or concept. Moreover, this theme for practitioners is embodied by the use cost characteristic which is closely associated with Fidelity. In other words, designers are concerned with time from the perspective of developing and detailing designs. For example: "You can just do that digitally over the top, or save up copies, or even have different layers to turn on and off in Digital Sketching. So, it's much faster to do iterative work or refinement work [in Digital Sketching]" and, "once I've got a more fleshed out idea, I move into digital sketching for quicker generation of ideas".

In contrast, student references to the time theme do not include such association with iteration, development or design thinking. Rather, students are either focused on time to complete the assignment or time associated with interacting with the tool. For example, "I wasn't very fluent before and after repeating the same task again and again. I got faster, for example, using paths on PS [Photoshop] to create lines or selections." and, "When working on the concepts, everything takes such a long time because I focus on doing it properly."

The way practitioners view time is a necessary compromise in iterative development, as explained by positive and negative references to Use Cost and Fidelity. For students, time is simply the time taken to achieve a seemingly fixed outcome. It is not seen as intrinsic to the design process. This difference in perceiving time characteristics concurs with research on the skills of novice versus expert designers. Expert designers put emphasis on iterating quickly and frequently, while novice designers are solution focused, iterating less frequently within a solution (Smith & Leong, 1998; Wynn & Eckert, 2017).

Perceptions with respect to usability are somewhat aligned. For students, they relate to ease or difficulty to use software and hardware. For example, “After practicing using a Photoshop [sketching] tools, my skill with Photoshop is getting better and more comfortable which makes my work tidier.” This is viewed as being focused on the creation of representations. Looking at the design tool characteristics that make up practitioners’ view on usability, we see designer’s references to compatibility and accessibility are more around the logistics of the design process. Designers’ referencing of flexibility is however somewhat different to the themes described by students. Flexibility references refer to usability with respect to changing/modifying and developing designs. So, similar to the difference in perceptions regarding time, practitioners’ perceptions of using the tool are related to the development of an emergent design or pursuing the design process.

Design tool characteristics coded within the representation theme again illustrate the way practitioners connect visualisations to iterative design process. For example, Fidelity is interesting as a characteristic described alongside time invested (use cost) to create visualisations. Likewise, level of detail is closely associated with the flexibility and vertical transformation. References to level of aesthetic align more closely to the student perspective of representing ideas. Finally, concerning the design thinking theme referenced by both groups, we contend there are relatively few references to design thinking as this is inherent within the subject matter. In other words, the use of visualisation tools to propose and iterate toward a solution is given and thus not explicitly mentioned.

Limitations

As discussed in the methods section, a limitation to the comparisons drawn between student and practitioner perceptions arises from the two forms of data collected, diaries versus semi-structured interview. While the full DTC framework is used to analyse practitioner data in the secondary analysis, this granularity was not achieved with student diary entries. As such it was not possible to draw equally deep insights in student perceptions to reflect against those of the practitioners. Hence, while we give discussion and explanation of practitioner views, it is not possible to further reflect on student views in the same manner. Although this is a limitation to the comparison of perceptions, the goal of the study is in essence to learn from the way practitioners approach visualisation, which has been achieved through the richer secondary analysis of practitioner data. Similarly, a further limitation stems from the methods selected. Opting for a method that allows designers to reflect means insights are drawn from different design projects. Each likely have different design considerations but also scope or length. As such direct comparison of data is not possible leading to our findings being limited to themes. As stated in the methods the intention of the study is explorative and to identify such themes. Further research would ideally create a more controlled experiment where variables such as designers’ experience/seniority, education in visualization tools and types of design task can be controlled creating greater comparability within the designer group as well as between students and designers.

The final limitation noted reflects the use of student participants from a single institution. Extending the study to include students from other institutions experiencing different visualisation courses would help to validate the data presented in this paper. Likewise, a broader set of practitioners from different countries, and including a mix of in-house designers, as well as consultants, would further validate practitioner perceptions.

Implications for design education

Educating students in visualisation inherently focuses on mastery of skills, i.e. accurately and fluently sketching ideas, or learning CAD software. Thus, it is not surprising that students emphasise the representation theme. The quality of representation is often the benchmark of how well they have mastered skills and hence closely related to final grades. Time taken is considered less. Moreover, we contend some students may place great importance on spending a lot of time to gain greater mastery and higher grades. In comparison for professional designers, findings show an emphasis on creating iterative designs in the most time effective manner. Thus, there is a major difference, even contradiction in the way tool use is perceived.

The key implication from differences observed is, how to teach skills in a manner that better connects the skill with designerly thinking and iteration? While 100% simulating the conditions in industry is impossible, we contend that greater emphasis on teaching students about tool qualities and tool selection, and how they influence design process and outcomes is required. At the very least by understanding characteristics of tools and comparing possible tools available, students might think beyond the skill and deliverable, and gain a sense of perspective about how the skill fits within the overall design process. Typically, course structures in higher education dictate that skills are often taught within a single unit with the intention that this knowledge is applied within projects. One recommendation is that projects may better integrate visualisation skills by also including teaching choice of tools and their relative pros and cons. We contend this would better contextualise the tool and in turn stimulate a greater consideration of purpose beyond creating the visualisation itself. Specifically, it could be worthwhile to apply a newly learned skill in projects of differing timeline and with substantially different deliverables. For example, using digital sketching to quickly create a concept versus using digital sketching in conjunction with other tools in an iterative manner over a longer project. These findings support recent recommendations in Brisco et al. (2020). While their study focuses on the use of digital tools to support collaboration, it provides a very current view that aligns in highlighting the value in educating students on the impact of tools and technology on the process of design.

Conclusions

An ever-increasing array of design tools are available to designers. As a consequence, design education is regularly challenged to keep up with trends by educating students in the use of design tools to ensure their employability in the design industry. This paper reports a study into the use of digital sketching, a relatively new digital visualisation tool. Specifically, it investigates thematic differences in the way students and practitioners perceive digital sketching between practicing designers and student designers. The overall goal being to improve our understanding of how the different characteristics of digital sketching inform its use. In doing so we reflect on how we educate students in selecting and using digital sketching along with other emerging visualisation tools.

Results exposed how practitioners perceive/reflect on the intent of visualisation with respect to advancing the design while students are much more focused on the task of creating visualisation. This reveals a contradiction in the way tools are perceived between creating visualisations to gain expertise or skill, versus creating them to advance the design process. As such we conclude that there is a need to reconsider the way visualisation skills are delivered. Visualisation is a skill that is best learnt through practice. However, contextualising the skill within the design process to understand how different characteristics of visualisation tools (such as fidelity and time invested) influence design outcomes is needed. As such, further research intends to focus on ways to balance necessary skill learning and development while also stimulating understanding of the way tools influence process and outcome. A second area of interest is to conduct similar studies in other new and emerging visualisation platforms such as the integration of augmented reality (AR) and virtual reality (VR) in visualising designs.

References

Abouelala, M., Janan, M. T., & Brandt-Pomares, P. (2015). Methodology of selecting CAM software package for education based on a questionnaire. International Journal of Mechanical Engineering Education, 43(2), 77-93.

Badke-Schaub, P., & Frankenberger, E. (1999). Analysis of design projects. Design Studies, 20(5), 465-480.

Brisco, R., Whitfield, R., & Grierson, H. (2020). A novel systematic method to evaluate computer-supported collaborative design technologies. Research in Engineering Design, 31(1), 53-81.

Camburn, B., Viswanathan, V., Linsey, J., Anderson, D., Jensen, D., Crawford, R., . . . Wood, K. (2017). Design prototyping methods: state of the art in strategies, techniques, and guidelines. Design Science, 3.

Crismond, D. P., & Adams, R. S. (2012). The informed design teaching and learning matrix. Journal of Engineering Education, 101(4), 738-797.

Evans, M., & Aldoy, N. (2016). Digital design sketching using the tablet PC. The Design Journal, 19(5), 763-787.

Evans, M. A., Pei, E., Cheshire, D., & Graham, I. J. (2015). Digital sketching and haptic sketch modelling during product design and development. doi:https://doi.org/10.1504/ijpd.2015.069323

Goldschmidt, G. (1991). The dialectics of sketching. Creativity research journal, 4(2), 123-143. doi:https://doi.org/10.1080/10400419109534381

Jonson, B. (2005). Design ideation: the conceptual sketch in the digital age. Design Studies, 26(6), 613-624.

Lawson, B. (2002). CAD and creativity: does the computer really help? Leonardo, 35(3), 327-331. doi:https://doi.org/10.1162/002409402760105361

Lawson, B. (2006). How designers think : The design process demystified. Oxford: Architectural Press.

Lutters, E., Van Houten, F. J., Bernard, A., Mermoz, E., & Schutte, C. S. (2014). Tools and techniques for product design. CIRP Annals, 63(2), 607-630.

Mathias, D., Hicks, B., Snider, C., & Ranscombe, C. (2018). CHARACTERISING THE AFFORDANCES AND LIMITATIONS OF COMMON PROTOTYPING TECHNIQUES TO SUPPORT THE EARLY STAGES OF PRODUCT DEVELOPMENT. Paper presented at the DS92: Proceedings of the DESIGN 2018 15th International Design Conference.

Pedgley, O. (2007). Capturing and analysing own design activity. Design Studies, 28(5), 463-483. doi:https://doi.org/10.1016/j.destud.2007.02.004

Pei, E., Campbell, I., & Evans, M. (2011). A taxonomic classification of visual design representations used by industrial designers and engineering designers. The Design Journal, 14(1), 64-91.

Purcell, A., & Gero, J. S. (1998). Drawings and the design process: A review of protocol studies in design and other disciplines and related research in cognitive psychology. Design Studies, 19(4), 389-430. doi:https://doi.org/10.1016/s0142-694x(98)00015-5

Ranscombe, C., Bissett-Johnson, K., Mathias, D., Eisenbart, B., & Hicks, B. (2020). Designing with LEGO: exploring low fidelity visualization as a trigger for student behavior change toward idea fluency. International Journal of Technology and Design Education, 30(2), 367-388.

Ranscombe, C., Zhang, W., Rodda, J., & Mathias, D. (2019). Digital Sketch Modelling: Proposing a Hybrid Visualisation Tool Combining Affordances of Sketching and CAD. Paper presented at the Proceedings of the Design Society: International Conference on Engineering Design.

Robertson, B., & Radcliffe, D. (2009). Impact of CAD tools on creative problem solving in engineering design. Computer-Aided Design, 41(3), 136-146. Retrieved from http://ac.els-cdn.com/S0010448508001334/1-s2.0-S0010448508001334-main.pdf?_tid=5ff78cf6-23ac-11e5-8a18-00000aacb35f&acdnat=1436166075_9dc812d1b0ed43b7f45b2238df0fb95a

Self, J., Dalke, H., & Evans, M. (2009). Industrial Design Tools and Design Practice: An approach for understanding relationships between design tools and practice.

Self, J. A. (2013). CAD Tools and Creative Design, Grounds for Divorce or Match Made in Heaven? CAD/CAM Review, 19(2), 36-43.

Smith, R. P., & Leong, A. (1998). An observational study of design team process: A comparison of student and professional engineers.

Thurlow, L., & Ford, P. B. (2017). Where have all the ideas gone? An anatomy of sketch inhibition among student designers.

Tsai, G., & Yang, M. C. (2017). How It Is Made Matters: Distinguishing Traits of Designs Created by Sketches, Prototypes, and CAD. Paper presented at the ASME 2017 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference.

van Passel, P., & Eggink, W. (2013). Exploring the influence of self-confidence in product sketching. Paper presented at the 15th International Conference on Engineering and Product Design Education: Design Education-Growing our Future.

Wynn, D. C., & Eckert, C. M. (2017). Perspectives on iteration in design and development. Research in Engineering Design, 28(2), 153-184.

Zhang, W. (2020). An Investigation into the Use of Digital Sketching during the

Early-Middle Design Phases in Industrial Design Practice. (Doctorate). Swinburne University of Technology, Melbourne.

Zhang, W., Ranscombe, C., Radcliffe, D., & Jackson, S. (2019). Creation of a framework of design tool characteristics to support evaluation and selection of visualisation tools. Paper presented at the 22nd International Conference on Engineering Design (ICED), Delft, Netherlands.

Design and Technology Education: An International Journal

26.3

How can comparative judgement become an effective means toward providing clear formative feedback to students to improve their learning process during their product-service-system design project?

Ivo Dewit, University of Antwerp, Belgium
Sarah Rohaert, University of Antwerp, Belgium
David Corradi, University of Antwerp, Belgium

Abstract

This study responds to calls to further investigate ways to make feedback more effective for students in the context of higher education. More specifically it scrutinizes the feedback practice, adapted to the exceptional reality of a partly on Campus, partly online semester–long Product-Service System (PSS) design project for first Master students of X at the University of Y. To do so, an established model of feedback (Hattie & Timperley, 2007) is used as a framework to seek answers to the research question: which types (and levels) of feedback are generated when applying Comparative Judgement (CJ) to guide the students' and teachers' feedback formulation? Following the model, first three types of feedback: feeding up; feeding back; and feeding forward and second, four levels of feedback are discerned: task; process; self-regulatory and self. The current study describes how first year Master students (n=72) and lecturers (n=4) apply CJ to formulate feedback. We evaluate which types and levels of feedback are formulated and received by the students, both towards and from their peers and teachers. Additionally, based on a post hoc survey and reflection paper, we list the strengths and weaknesses of CJ as a method to help students to formulate, interpret and receive feedback. Finally, we identify various opportunities to improve CJ based feedback during product development cycles and its impact on learning and self–assessment of the own project process and (intermediate) results quality, and metacognitive strategies for learning.

Keywords

design education, formative feedback, product-service systems, comparative judgement, metacognition and learning

Introduction

Kluger and De Nisi's (1996) meta-analysis of feedback was a catalyst for acknowledging and investigating the highly variable effects of feedback on learning, both positive and negative. Further research demonstrated that a large amount of feedback by teachers is rarely used and implemented by students (Carless, 2006). This study responds to calls to further investigate ways to make feedback more effective for students (Brooks et al., 2019; Hattie et al., 2016; Shute, 2008). Hereto we explore if and how Comparative Judgement (CJ), i.e., comparing and ranking 2 or more products, can support the formulation of effective formative feedback. We do so in the context of a partly on campus, partly online semester–long Product-Service System

(PSS) design project for first master students of X at the University of Y during the exceptional fall of 2020, profoundly marked by the second wave of the Covid-19 pandemic.

Teaching and learning context: Product-service systems

This paper discusses the findings of a research study focusing on the question of whether CJ can support the formulation of clear, actionable formative feedback to guide the students' learning process. Specifically, this question will be framed within the context of guiding a PSS design learning process. Now what does a PSS design project entail and which kind and frequency of feedback does it call for? PSS design projects seek to create systems in which products and services are designed in unison and reinforce each other. As such, PSS design requires a structured process with a broad scope to embrace the integral nature of complex system–level challenges and potential solutions. As such, it fits well with a design pedagogy vision, supported by Tovey (2015), who claims that designers should become generalists in as wide a range of content as possible, as the wider the reach of their knowledge base, the more likely the creative inspiration to address complex challenges. This will allow designers to work on multifactorial and global challenges, as well as it will help them to address dynamic problems that evolve as design projects develop (Rittel & Webber, 1973). This view is supported by theories about critical reflection in critical dialectic approaches (Habermas, 1978), which requires students to incorporate multiple perspectives into their thinking and eventually into their designs.

To incorporate multiple perspectives throughout their design process, the students are taught the 'PSS Design Toolkit' (Dewit et al., 2018) which provides the tools to observe, interact with and receive feedback from various stakeholders and guidance on which tools to use towards which ends in which design phases. This toolkit supports the students to gradually create innovative interactions between consumers, the products and services they use, and the providers offering them. However, there is a big difference in having access to the right tools, having the competences to use them, and being able to question the overall approach independently (Dewit, 2019; Dewit et al., 2021). In cognitive terms, learners are required to make links and translate between different levels and aspects of the integrated product and service development process, while considering all interacting PSS aspects and actors. At the same time the learners do have to take care not to lose sight of the 'big picture', the integrated whole.

From the part of the learners, advanced analytical thinking (to understand every small part of a product or service), and synthetic competencies (to understand how all parts combined can lead to an innovative design) are required, just like metacognitive awareness (Puryear, 2015) (to understand why a certain combination of subparts leads to a better service, while another combination doesn't) (Medola et al., 2021) Receiving adequate, clear and regular feedback, both from project stakeholders and from teachers and peers is key to further develop above mentioned competencies (Callender et al., 2016), as these are necessary to act on new insights and reframe their thinking.

Therefore, from the part of the teachers, the scheduling of frequent checkpoints throughout the learning period gives students multiple opportunities to demonstrate their learning and project progress. These checkpoints provide teachers with an information of how their students are proceeding towards achieving the learning goals (Brooks et al., 2019). Furthermore, they provide various opportunities to give formative feedback to guide the learning process. The most important activities for teaching staff of educators in a design studio (with analytical, synthetical and metacognitive learning goals) is twofold: (1) they provide critique, constructive feedback and (2) they teach fellow students to criticize each other's approaches, to facilitate critical thinking in order to question their preferences and knowledge about the given problem (Gray, 2013). This pedagogical tradition aligns with theories about critical reflection involved in the constructivist pedagogical approach (Schön, 2017). To formulate critique and feedback in the form of questions has at least two advantages (Wiliam, 2013): questions implicitly cause thinking in students and student responses provide the teacher with information about the learner's current understanding in order to guide reflexive instructional practice. When teachers perceive student work samples and responses as feedback to themselves about the effectiveness of their teaching, they can indeed learn through critical reflection (Hattie, 2009). Even more than in traditional product design, the design students are challenged to cope with an increase in complexity, i.e., a multitude of interacting variables and stakeholders to consider. Hereto, the flexible use of clarifying representation and communication skills are key enablers to communicate clearly about the various design phases in order to receive constructive feedback to improve the PSS concept.

To exchange feedback between students and teachers, we used Comproved as a CJ–system, which was integrated into the university Learning Management System (LMS). For more information, see the Comproved practical guide for instructors (https://comproved.com/wp-content/uploads/2021/02/022021_Practical-guide-instructors.pdf) and the Comproved practical guide for participants (https://comproved.com/wp-content/uploads/2021/02/022021_practical-guide-participants.pdf).

Theoretical Background on Feedback in Higher Education

Comparative judgement

A growing body of literature supports the notion that comparative judgment can help learners and assessors in different learning and working situations (Lesterhuis et al., 2016; Van Gasse et al., 2017). CJ asks an assessor to compare two products and rank one product in relation to another. These products can be both small scale such as a short presentation, a paper or a drawing; and large scale such as a masters' thesis or a full fledge solution for a real–life solution to a problem. In order to realize multiple comparisons using multiple judges (students, teachers and/or external assessors), a measurement scale can be created using the Bradley-Terry-Luce model (Bradley & Terry, 1952; Luce, 2005) showing the relative quality of each product (Pollitt, 2012). Furthermore, ideally each product receives detailed feedback. A major strength of CJ, in terms of assessing difficult-to-specify constructs such as a product design process, is that the result is based on the collective expertise of the raters. Or its validity is anchored in what is valued by the community of practice within a given discipline (Jones et al., 2015).

Studies indicate CJ can be beneficial during a learning process (Bartholomew et al., 2019; Bouwer et al., 2018). CJ overcomes certain shortcomings of rubrics, which are often far too abstract for students to really grasp what 'quality' is, even those which specify performance levels and/or standards for each criterium, (Brookhart, 2018). CJ shows exemplars to students which are more relevant when it comes to understanding what quality is (Boud, 2000; Carless & Boud, 2018; Nicol & MacFarlane-Dick, 2006). When analyzing exemplars, students experience for example how high-quality products differ from average products (Orsmond et al., 2002).

Furthermore, learners are taught to reflect why product “A” is better than product “B”, and learn to articulate why one product is better, worse or equal to another when they compare products. This thinking process is often referred to as metacognition, whereby the learner attempts to understand and explicitly name the intricate aspects which define why one product is better than another. When learners compare each other’s PSS, both during and at the end of an educational process, learners also compare each other’s analytical and synthetical thinking process, which might improve their metacognitive awareness of the product development process.

Another advantage in comparison to other types of assessment (e.g., rubrics) is that CJ focusses more on the holistic process and the holistic project result (Figure 1). Hereby the whole is more than the sum of its aspects. (Goossens & De Maeyer, 2018; Van Gasse et al., 2017). The PSS effort is directed towards a multilayered, complex challenge. A holistic assessment, building upon frequent formative feedback checkpoints is expected to result in a more valid grading for such complex assignments.

However, not all studies report overall or exclusively positive effects. Bartholomew et al. (2019) for example found that feedback given by students in a CJ setting can be rather superficial, e.g., mainly limited to the aesthetics of a certain design and rarely addressing more in-depth issues or providing more holistic feedback. Other studies have indicated that not just any kind of products can be compared. Comparisons of very extensive products with large quantities of information (such as >15 minutes movies), or products which are too different, (Bartholomew et al., 2019; Slovic & MacPhillamy, 1974) do not lead to reliable results.

Types and levels of feedback

Hattie and Timperley’s (2007) Model of Feedback identifies different types and levels of feedback and considers the differing learning states of students. The different types of feedback are differentiated by the kind of question they answer. Feed Up (1) informs students about the goals, the learning intent, thus about: “where am I going?’ Feed Back (2) informs them about “how am I going?”, while Feed Forward informs them about “where to next?” However, not all types of feedback are considered equal. Gamlem and Smith (2013) state that students perceive feedback to be most effective when it includes improvement focused feedback that clarifies the next steps for learning. Boud and Molloy (2013) also emphasize that feeding forward should be an innate quality of feedback. Each of these feedback questions works at four feedback levels: task, process, self-regulation and the self-level.

At the task level, feedback is given about the specific requirements of the task, about how well the tasks are understood/performed. At the process level, feedback is directed towards the processes, skills, strategies and thinking required by the learner to understand and perform the task (the PSS design in our particular learning context). At the self-regulation level, the students are challenged to use deep learning principles such as relational thinking and self-monitoring to compare, direct, regulate and adjust their work in relation to the required standards (Butler & Winne, 1995). At the self-level, feedback focuses on personal, mostly positive evaluations of the learner, often associated with praise. In terms of implementation, Brooks et al. (2019, p. 27) indicate: “it is important to emphasize the ongoing interaction between the three feedback types rather than seeing them literally as boxes to be ticked off in linear fashion. Likewise, the progression of feedback level is non-linear and relies on teachers' use of formative assessment practices to check their students' level of learning."

Research Question

As far as we know, no research into CJ has indicated what the quality is of peer- and teacher feedback and how this contributes to the design process and the acquisition of design competencies. As such this study seeks answers to the main research question: How can CJ become an effective formative assessment-tool to help students and lecturers provide clear formative feedback to students to improve their learning process during their PSS design project? As such, this study seeks to support the teachers to consider their impact and peer students' impact upon learning and to provide impetus to adjust instruction and future feedback processes during the assessment practice of the particular learning context of PSS design.

To gain insights into our main question, we formulate sub questions to gain further insights.

First, we explore (a) which types (and levels) of feedback are generated when applying CJ to guide the students' learning process and design project progress?

Second, we tentatively investigate (b) if and how the quality of the feedback given during CJ checkpoints during the PSS design process, can be further improved. Hereto we investigate:

(b1) which strengths and weaknesses do students experience with CJ-generated feedback?

(b2) which strengths and weaknesses do teachers experience with CJ-generated feedback?

(b3) which opportunities can be identified to improve the CJ-generated feedback?

Our study thus aims not only to explore which types and levels of feedback CJ based assessment with Comproved seems to foster. We also seek to better understand which are the perceived strengths and weaknesses by students and teachers of CJ with Comproved and which opportunities of improvement can be pinpointed for formative feedback during a PSS learning process.

Methodological Approach

In this study, we describe a case-study of a Masters' design course with seventy-two master students that were placed into teams of four students. Each team had to collaborate -partly on-campus, partly online, due to the worldwide Covid-19 pandemic - on a semester-long PSS design project. Most students did not have previous experience with the PSS design toolkit, neither did they have experience in PSS design. To achieve the objectives for this twelve-week design course, student teams are expected to generate user insights and explore new opportunities to define and design a relevant PSS concept for this year's prompt 'The Future of Urban Health' and its proposed subthemes: (1) Your city, your vaccine (fit city); (2) The super responsive /resilient hospital; (3) The city without a hospital (micro hospitals).

Each week one third of the student teams has been asked to present their current project status in a short presentation at the start of the weekly consultation day, resulting in three checkpoints for formative assessment using CJ. Half-way in their design process, all student teams present their intermediate project results in the form of a presentation during a mid-term jury. By the end of the project all teams once again present their project results during the final project presentation. Upon these three different project checkpoints, students, three aspirant teachers and four experienced design coaches provide formative feedback on the project progress. During the course we used a CJ tool, Comproved, to allow students to give feedback and rank each other's weekly, mid-term and final presentations. The required presentation form was a short video/movie (with a duration ranging from min. five to max. ten minutes) on their PSS project status: their design process, progress and intermediate project results, which allowed a comparison between the different student teams and their project achievements so far. In the middle and at the end of the design course, an assessment moment was organized to evaluate the projects. The evaluative role of CJ during the project process was both formative (for weekly consults, mid-term and final presentation) and summative (for the final presentation). The feedback, provided on the final assessment was both formative and summative because (a) feedback was formulated as such that it is applicable to future design projects or (b) when students do not pass in June, the feedback is applicable to improve their PSS design for resubmission in September.

In the following paragraphs, we will detail the relevance of a holistic assessment in the context of product development education. Table 1 on the next page offers an overview of the various checkpoint with feedback during the PSS project process in 2020 versus 2021, to show the impact of Covid-19.

Table 1. an overview of the various checkpoints with feedback during the PSS project process in 2020 vs 2021

Feedback check-points	Weekly design day		Mid-term assessment Formative feedback for each team	Final assessment Summative* feedback for each team
	Weekly consult timeslot to discuss project progress with 2 coaches Formative feedback for each team	Presentations on project progress by 1/3 of all teams to the whole class Formative feedback for 1 third of all teams each week		
Pre-pandemic feedback from other students	Internal team member feedback; possibility to watch other teams' work on paper & to ask them for informal feedback on Campus	All teams can give feedback (and evaluate their own progress in comparison) after the presentations by 1/3rd of all teams on campus	All teams attend all presentations in an auditorium on campus, and are stimulated to ask questions & give feedback to all presentations	All teams attend all presentations in an auditorium on campus, and are stimulated to ask questions & give feedback to all presentations. Students grade each other's expo posters, based upon 6 criteria
Pre-pandemic feedback from teachers	Oral feedback during +/- half an hour consults from a tandem of 2 coaches, live on Campus	Feedback by 4 teachers after each presentation	Grades - 6 grades for 6 criteria to access the PSS: Fit with nodes: Relevance; underpinning; logical build-up; elaboration; originality	Grades - 5 grades for 5 criteria to access the PSS: Relevance; Verification & testing; logical build-up; elaboration and completeness; originality

			- 2 grades for quality of presentation and quality of report		- 3 grades for quality of presentation, expo poster and report	
In-Pandemic feedback from other students	Internal team feedback and possibility to watch other teams' work online on MURAL & to ask them for informal feedback online	6 teams have to upload & rank each other's video & provide feedback to support each ranking on Comproved (evening before design day); the other teams can watch these videos	Written feedback based on Comproved Videos, guided by 4 criteria (on average 102 comments from 40 students for each team/project)		Written feedback based on Comproved Videos, guided by 4 criteria (on average 102 comments from 40 students for each team/project)	
In-Pandemic feedback from teachers	Oral feedback during +/- half an hour consults from a tandem of 2 coaches, pre & post-lockdown: on campus, during lockdown: online + written feedback posted on team's canvases on MURAL	Oral feedback by 2 coaches (and 2 PhD students) during the online consults of the 6 teams	Written feedback based on Comproved Videos, guided by 4 criteria on average 8 comments from 3 experienced & 3 novice teachers)	Written feedback for subparts: prototyping quality, concept, video presentation, based on rubrics	Written feedback based on Comproved Videos, guided by 4 criteria (on average 8 comments from 3 experienced teachers & 3 novice teachers)	Written feedback for subparts: prototyping quality, concept, video presentation, based on rubrics

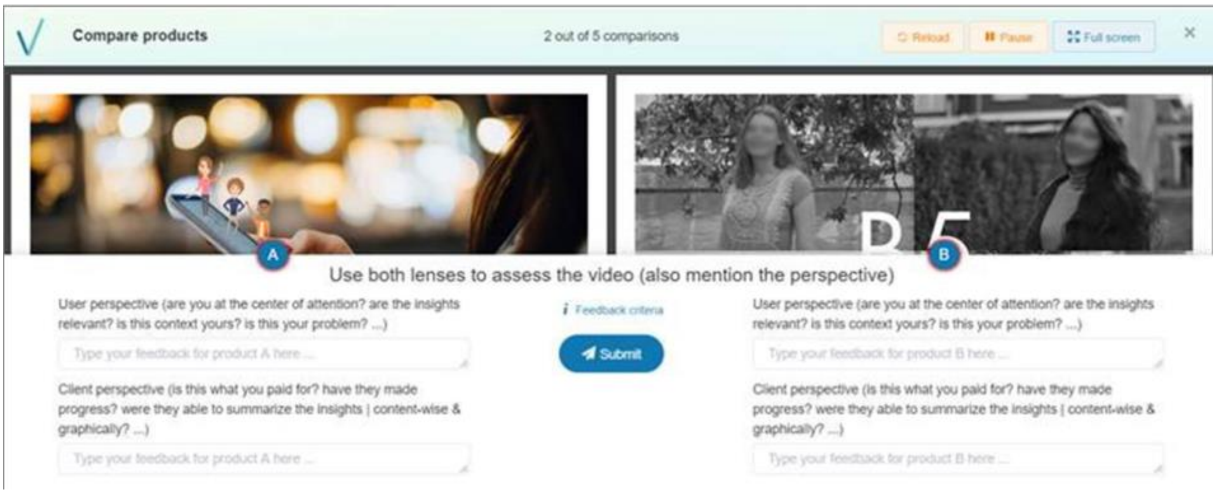


Figure 1. An example of a comparative judgment checkpoint in Comproved, which asks students to indicate either A or B as the better product and provide feedback based on certain criteria.

Students show their project progress online on Mural. Mural is a digital whiteboard for sharing and structuring unstructured information (e.g., pictures or audio files). It enables virtual collaboration on creative work, which can take place simultaneously or asynchronously (Lattemann et al., 2017) (For more details, see: https://www.mural.co/).

While pre-pandemic, the students received large A2 paper posters, printed with PSS tool templates to collaborate on, during the pandemic these templates were provided online to all teams in Mural, as backbone to support the design process of students who had to collaborate online in a lock-down situation. Thus, the student teams could collaborate online on Mural Canvases with and without PSS tool templates in order to share their project progress and prepare their weekly consult moments, while teachers could track student teams' progress on Mural, leave post-it notes with feedback and suggestions and refer student teams to other team's Mural Canvases as referential exemplars for the right level of elaboration of certain tool applications or project progress expectations.

Qualitative data gathering and data analysis

A qualitative study has been set up to better understand how CJ influences the students' learning process. In Comproved, we ask students to provide feedback on positive and negative aspects of both the PSS concept and the video, and strong and weak points of the PSS design, from a user and a client/investor perspective. The total amount of feedback on all projects from all teachers and students for the midterm checkpoint comprised 24,499 words, distributed over 2,749 feedback lines. A variety of qualitative data gathering techniques has been used in this study to obtain detailed information about the influence of CJ with Comproved on feedback types and levels. This approach permits data triangulation, as advocated by Yin (2016) to strengthen the credibility of a study by detecting convergence on outcomes. Two researchers independently screened the types and levels of feedback obtained using Comproved. Inconsistencies were discussed until consensus was reached.

Two researchers also divided the obtained students' and teachers' feedback about their CJ experience with Comproved in three broad categories: (1) perceived strengths, (2) perceived weaknesses of CJ, and (3) identified opportunities to improve the CJ-feedback quality. Afterward, feedback on which we did not reach consensus, was discussed and recategorized.

To answer the b1, b3 and b5 questions, two researchers have independently screened the students' reflections on their general learning experience (of a maximal length of half a A4 page) for feedback and comments from the students about their experiences and evaluation of the CJ-based feedback quality on Comproved. All students (n=72) submitted a reflection page. A qualitative analysis of the students' responses to an additional qualitative survey, with both broad and specific questions on educational quality (n=18) (Spooren et al., 2007) was also carried out, based on content analysis. This survey aimed to obtain more detailed insights into the educational experiences. To avoid bias, we did not ask specifically about Comproved, neither in the instructions with guiding questions for the reflection page, nor in the survey.

The teachers' feedback about their experiences and evaluation of the CJ-based feedback quality has been gathered by asking the four experienced design coaches to reply in writing to the questions b2, b4 and b5. The three apprentice teachers have not been included, as this semester was their first teaching experience. Therefore, they did only participate partly (providing the teams' short video pitches from feedback) instead of completely to the CJ evaluation & feedback process.

This article has tested a CJ tool in the context of a complex (i.e., real-life) PSS design assignment. Besides the measurement concerning students' face validity with the instrument, the presented results of the CJ software show stability and reliability in two ways:

1. Power in numbers: 6 times 24 users (weekly basis) (n=144) and in the middle of that 1 time 72 users for the formative use of CJ, and in the end, again data from 72 users for the summative use of CJ provides significant reassurance that the results we have presented are meaningful.
2. Reliable scaling: To compare the same products by multiple raters results in a more objective assessment of the products compared to more subjective grading using rubrics (criteria and interval scoring) of design products by their professors. This, because comparing is a more natural way of assessing (Laming, 2004) in which people tend to be better than in making absolute judgements (Thurstone, 1927).

Findings and discussion

To gain insights into how CJ can become an effective means to provide clear formative feedback to students, we investigated which types (and levels) of feedback are generated to guide the students' learning process and design project progress when applying CJ. When commenting on the value of CJ-generated feedback, the students and teachers clearly indicate there are considerable differences in perceived value and quality of CJ-based feedback on Comproved between the individual students and between the student peer feedback versus the teacher feedback.

Therefore, we tentatively explore if and how the quality of the feedback given during checkpoints, can be further strengthened while using CJ. Hereto we have screened the feedback received from the students and the four experienced design coaches about their experiences and evaluation of the CJ-based quality of feedback. How do students perceive the influence of CJ on the feedback they give and receive during the PSS design process? Do students feel CJ is a valuable tool to give, receive and interpret feedback?

Types and levels of feedback generated by CJ (Research question a)

The majority of feedback on the positive aspects is retrospective, thus more of the Feed Back Type, providing confirmation for certain choices made by the student teams. Also, in other studies (e.g., Brooks et al., 2019) Feeding Back was the most common type of feedback.

However, it is noteworthy that the comments on the negative aspects include more points of improvement. As such, they generate more interesting actionable, formative feedback of the Feed Up Type and also some of the Feed Forward Type for the students, which support the teams more to know which next steps to take, than Feed Back would do (Boud & Molloy, 2013; Gamlem & Smith, 2013). When we compare the levels of feedback, present in the feedback overview of Comproved, the task level is clearly dominant, with a second place for process level feedback. The self-regulatory is absent and the self-level scarcely appears amongst the feedback, generated by Comproved. These findings replicate studies on feedback in education, where firstly, process level feedback was consistently reported to be less frequently occurring to task level feedback (Brooks et al., 2019; Gan, 2011; Van den Bergh et al., 2013). Secondly, the 3 latter studies found feedback was directed to self-regulatory levels on only 1 to 2% of occasions relative to the other feedback levels.

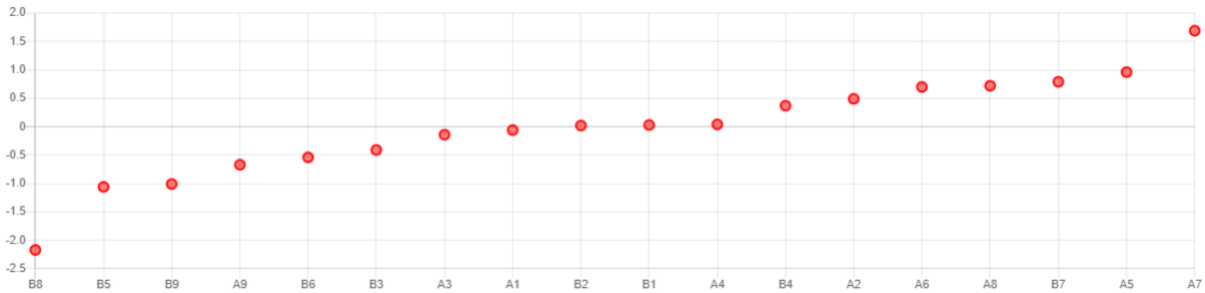
However, we may also attribute a partly responsibility to the instructional design in the Comproved set-up, as students have only been asked to compare the videos and PSS concepts of other teams, not the video of their own team versus the video of another team. It might be interesting to include these comparisons between own and other's work as well. However, one senior teacher (T1) expressed a genuine concern that this might lead to opportunistic and strategic ranking by students, who might rank the own project higher than any other, even if the other might be clearly superior to the own work. The guiding questions, which we implemented in Comproved, rather steer towards feedback on the task level, less on the process level and not at all on the self-regulatory and self-level.

Furthermore, a short instructional video on Comproved, pointing out the advantages of more Feed Up and Feed Forward Types of feedback, when possible, formulated in the form of questions (Wiliam, 2013), with equal attention to the tasks and process level might contribute to richer and more instructive, constructive feedback.

Perceived strengths of CJ

As experienced by students (Research question b1)

- CJ stimulates more peers to formulate & receive more feedback on each other's project status: "If we had given a live presentation in an auditorium for the mid-term, we would not have received as much feedback as we do now"
- The possibility to comment on the positive and negative aspects allowed students to obtain constructive feedback from peers on their work: "I found it very instructive to make a video to show our progress as a group, because we learned to present better (a) but this was also the ideal moment to critically review our work (b) while making the video". "Making the short interim progress videos helped to motivate us (c) and to prepare us for creating the final video(s) (d), and the other videos were also inspiring for our own work". "The videos seemed to me to be more work than a regular morning presentation of the project, but like this we learned to work better with première pro, resulting in a new skill for the portfolio".
- The CJ software offers an overview of all the other products so students can explore them still on later occasions, to (a) see the progress and approach of other teams, (b) assess their own progress and presentation skills in comparison to others, and (c) asks feedback from others.
- CJ indirectly stimulates an overall better presentation quality of the students' products, by challenging them to present their project process in a self-explanatory 5 till 10 minutes video.
- The CJ software offers the ability to open the rankings so that both place (quality rating) and feedback on other work is available (see Figure 2). This is perceived as a great learning opportunity.



Product	Type	Group	Participants	Rank	Grade	Submitted
ipo midterm presentation	Blog post	B6	QV SA LP +1	14	10.08	5 months ago
Midterm video B1	Blog post	B1	FV TM ZM +1	9	14.91	5 months ago
GROUPB8 MIDTERM VIDEO	Blog post	B8	MH PT RM +1	18	6.02	5 months ago
GroupA7_Midterm_Video	Blog post	A7	GJ MC TC	1	16.99	5 months ago

Figure 2. The comparative judgment software allows students to view and compare their rank (grade when selected by the teachers) and feedback with other work.

As experienced by four experienced design coaches (T1>T 4) (Research question b2)

- CJ allows for different views of the results, both from students and teachers (T2), thus it results in better evaluations by and for all parties (T2). This may foster metacognition in terms of learning to communicate complexity and achieve simplification with the right representation.
- CJ stimulates a dialogue within the team and a competition between teams (T2). The benchmark between peers creates awareness in terms of better and worse, but also in judgement of best.
- Students can already proceed with the CJ feedback, even without their weekly consults (T2). In terms of envisioning possibilities and next steps (Feed Forward and Feed Up).
- Students generally don't want to offend anyone, out of some sense of justice (T1). Even so, it makes them think about giving feedback and gives them a better understanding of the design process).
- It objectifies your own assessment, compared to what students had ranked and the feedback they had given (T3). You can question yourself as teacher, offers a good benchmark.
- CJ requires students to review the results and express an opinion (T3).

Perceived weaknesses of CJ

As experienced by students (Research question b1)

- For interim products, student preferences go to the small-scale short presentation, a paper or a drawing. For large-scale products – describing full fledge solutions to a real-life problem (PSS design) – students prefer to compare and assess fewer products. They expect their peers would watch it more carefully and give more accurate feedback: “It felt like only a part of the video (product) was viewed each time, resulting in less informed reactions from people who did not completely understand, or gave comments that were totally irrelevant, not useful, or at least much less than we (receiving the feedback) expected."

- Students also perceived a certain difficulty in interpreting the value of certain comments. For example, there is no hierarchy or difference made between the feedback on the product being from experienced design coaches, aspirant teachers or students. There is also no distinction made between the feedback of students who have dutifully seen the whole video, or who have only seen the first minutes. The teachers now compensate for this lack of differentiation between critiques, by discussing with the team the received CJ feedback, emphasizing priorities and separating the valuable from the confusing or irrelevant comments.
- CJ products must always be uploaded one day before the CJ, which results in a tighter deadline and more time pressure, as making a video takes much more time than e.g., preparing a presentation. Students also rightfully commented that there were no supportive courses to teach them how to produce a good video, leading to a much more time intensive learning-by-trial-and-error.

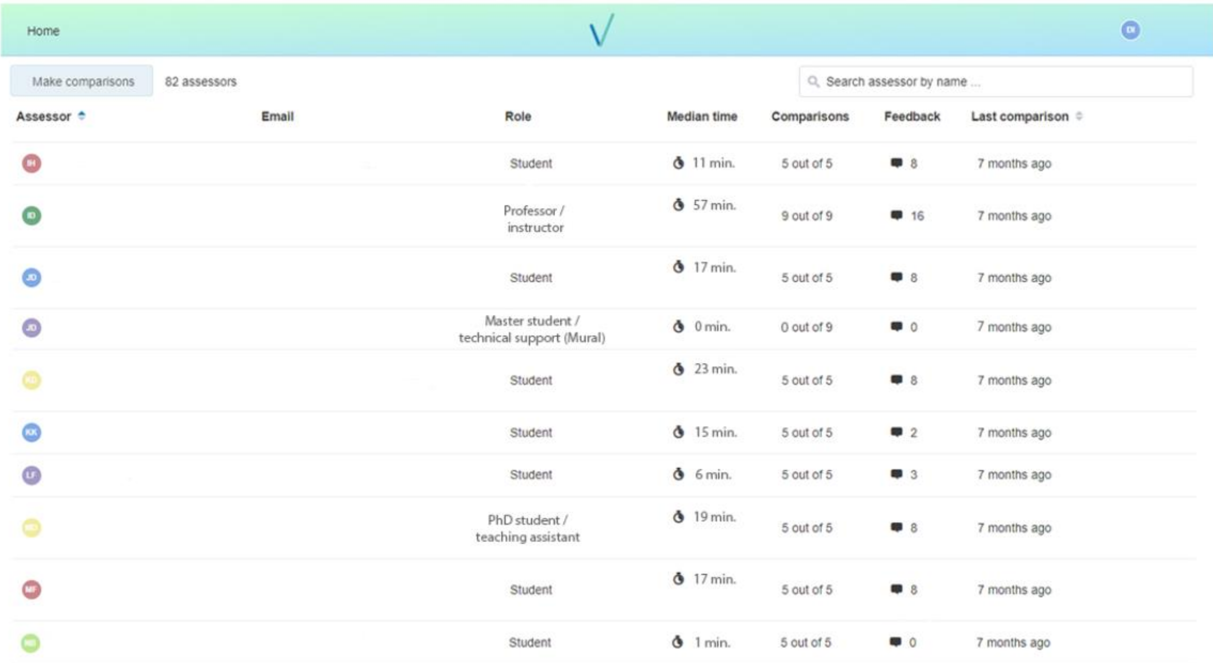
As experienced by four experienced design coaches (T1>T 4) (Research question b2)

- During CJ, a strategy of giving oneself a biased place in the group is always at play (T1). This is a concern that stands when giving scores, not when giving a rank and feedback.
- CJ obliges to give a ranking. Perhaps this is not justified. I don't see why students who have done well should necessarily still be distinguished from each other (T1). Referring to the 'excellence gap', differentiating up should not be an issue and provides feed-up for future design projects and as designer-professionals-in-the-making.
- A relatively high number of comparisons is necessary to reach a reliability over 0.7, (T2), e.g., difficult for intermediate (weekly) comparisons with only 1/3rd of the student teams, or when teachers divide the work (comparing lesser products each) for multiple deliverables.
- With CJ, it feels like the objective quality of learning goals / final terms is not assessed (T1). Results are less open for dialogue between teachers.
- You can only choose product A over B or vice versa and not judge A and B as equally good. It's not nuanced enough, it's more interesting to be able to say: I think a or b is better because there has been a lot of progress compared to last time, the story is right, this criterion scores higher and lower for A or for B (T3).
- CJ absorbs so much time, we should rethink the 'products' students upload to be shorter (T3).

Improvement opportunities for CJ -generated feedback (Research question b3)

- The instructional design can be improved. During the comparison, a clearly visible reminder or checklist to give better guidance about which feedback is expected for which criterium to obtain richer, more qualitative and qualitative feedback is necessary, best positioned near the feedback boxes. From following student's comment: "Rating is so black and white, sometimes the idea of product A was better than product B but the product (video) was worse. It felt like comparing apples with pears" we learn that students experienced a dilemma about which aspects to focus on, when choosing the better 'product' and when considering which feedback to give. Thus, we find that some students only base their comments on the video, others only about the underlying PSS concept, when they provide feedback from a user's and clients perspective, as shown in figure 1.

- A clear distinction should be made between CJ feedback coming from an experienced design coach versus from a meticulous or sloppy peer. However, information on who the feedback comes from and how much time has been taken by each particular "assessor" is available as the back end of the Comproved software, as shown in figure 3. Unfortunately, this info is not made available in an anonymous way to the student, nor to add a new layer to differentiate and rank feedback, according to which feedback is expected to be more trustworthy and reliable or less.



Assessor	Email	Role	Median time	Comparisons	Feedback	Last comparison
		Student	11 min.	5 out of 5	8	7 months ago
		Professor / instructor	57 min.	9 out of 9	16	7 months ago
		Student	17 min.	5 out of 5	8	7 months ago
		Master student / technical support (Mural)	0 min.	0 out of 9	0	7 months ago
		Student	23 min.	5 out of 5	8	7 months ago
		Student	15 min.	5 out of 5	2	7 months ago
		Student	6 min.	5 out of 5	3	7 months ago
		PhD student / teaching assistant	19 min.	5 out of 5	8	7 months ago
		Student	17 min.	5 out of 5	8	7 months ago
		Student	1 min.	5 out of 5	0	7 months ago

Figure 3. The comparative judgment dashboard (only visible for teachers) offers an overview of the time spent and number of feedback comments given by each student.

An indication credibility by Comproved could stimulate students to raise their feedback game and thus contribute to following point of improvement:

- More specific attention from teachers and peers, is indicated to raise feedback quality and variety in feedback types can support students in becoming more competent in providing constructive Feed Back, Feed Up and Feed Forward at the four levels. Providing more guidance and constructive Feed Back, Feed Up and Feed Forward at the four levels by means of regular coaching sessions can strengthen the further development of their pedagogical and design critique competences and design management skills.
- Specific timeslots should be reserved during the design exercise, so students and design coaches must reflect on their own and each other's feedback quality and underlying worldviews and biases, thus stimulating meta-cognition.
- Comproved should be more efficient in the follow-up of video-submissions and the processing of back-end information.

- Comproved should also provide the option of ‘product’ A is equal to ‘product’ B. Now you are forced to indicate that A is either better or worse, which is frustrating and seems unfair when both seem to be of the same quality.
- Students should be able to see a dashboard, to see how well they score on specific criteria, that keeps track of their evolution throughout the design process.
- As a teacher or student, it would be interesting to be able to benchmark and see how far you deviate from others.

Conclusions

Contributions of the study

This article describes which types of feedback Master students of Design and teachers formulate when they use CJ to provide feedback to each other, about the project progress during the design, and the final ‘product’ using CJ. Our findings show that the students perceived CJ to be helpful during and at the end of the design process, with certain reservations, as listed under “weaknesses”. Furthermore we discern a crossover between CJ and PSS design learning objectives:

- CJ motivates students to envision early-stage conceptualizations and representations of the design (process), as such new prospects are opened up, envisioning possibilities and next steps are identified, supported by constructive Feed Up.
- A continuous comparison of intermediate ‘products’ supports student designers to make their doing, making and inventing explicit, which enables communication with others and provides a better understanding of the design process, which otherwise would remain largely tacit knowledge (even for the designer).
- CJ allows to streamline the design process, makes it consistently comprehensible and provides a benchmark between peers. Specifically for PSS design, designers should be apt to deal with communicating its complexity and achieve simplification by making the right representation choices. Comproved challenges them to produce self-explanatory, attractive videos to “sell” their PSS concepts to peers, future users and investors.
- Unless provided, a set of alternative solutions - to compare with - is usually not a given. CJ allows comparisons between designs in terms of better and worse, but also in judgement of best.

We also suggest how CJ-generated formative feedback may be improved.

Limitations of the study

Obviously, there are general limitations with respect to the fields of application of our results. In this paper, our focus is on using CJ, relying on the above-mentioned Comproved software with foremost formative feedback purposes, within an educational setting where students are designing PSS. We did not compare the results with other types of feedback systems. The additional qualitative survey in this study is also limited by its respondents (n=18). However, we argue that the students were overburdened at that time.

PSS and its complex representations require a holistic approach when it comes to feedback. COVID-19 brought new challenges to the design process and asked for additional skills to facilitate and guide online collaboration and meetings to receive and give mutual feedback amongst PSS development teams, multiple stakeholders, clients and users. We do not claim to generate a representative sample, nor to generalize the results to other contexts, but rather to share our insights and opportunities to improve CJ-generated feedback in an online or hybrid teaching landscape.

Future research

A new hypothesis for future investigation thus emerged: might it be possible that a positive relation can be found between the quality (variety of types and levels) of feedback students provide to other student teams and the quality of their own PSS design results. In other words: do better design critics, providing more accurate and in-depth peer feedback, make better designers?

While CJ has proven to add to the understanding of the value of peer evaluation as part of students' active design education and reflection in this specific course, we still want to investigate more profoundly if and how CJ can contribute better to (indirectly) develop certain valuable skills and competences, necessary for our students, the design-professionals-in-the-making.

We would like to improve the formulation of instructions in Comproved, e.g., in the form of questions, to harvest more actionable feedback and steer more toward feed-up at a process level. Thus, we can evaluate if this leads students to formulate more qualitatively rich and reliable feedback of different types and different levels. As a possible next step for this research, it would be worthwhile to exchange experiences with design academics, who make use of CJ software to evaluate their students' design projects, with a comparable degree of complexity and duration (one semester) as the PSS project assignment. How do they seek continuous improvement in the way they provide feedback during a design project, evaluate the learning progress of their students and motivate them to become valuable co-evaluators of their peers?

References

Bartholomew, S. R., Zhang, L., Garcia Bravo, E., & Strimel, G. J. (2019). A Tool for Formative Assessment and Learning in a Graphics Design Course: Adaptive Comparative Judgement. Design Journal. https://doi.org/10.1080/14606925.2018.1560876

Boud, D. (2000). Sustainable assessment for long term learning. Stud Contin Educ., 22(2).

Boud, D., & Molloy, E. (2013). Rethinking models of feedback for learning: The challenge of design. Assessment and Evaluation in Higher Education, 38(6). https://doi.org/10.1080/02602938.2012.691462

Bouwer, R., Lesterhuis, M., Bonne, P., & De Maeyer, S. (2018). Applying Criteria to Examples or Learning by Comparison: Effects on Students' Evaluative Judgment and Performance in Writing. Frontiers in Education, 3. https://doi.org/10.3389/feduc.2018.00086

Bradley, R. A., & Terry, M. E. (1952). Rank Analysis of Incomplete Block Designs: I. The Method of Paired Comparisons. Biometrika, 39(3/4). https://doi.org/10.2307/2334029

Brookhart, S. M. (2018). Appropriate Criteria: Key to Effective Rubrics. In Frontiers in Education (Vol. 3). Frontiers Media S.A. https://doi.org/10.3389/feduc.2018.00022

Brooks, C., Carroll, A., Gillies, R. M., & Hattie, J. (2019). A matrix of feedback for learning. Australian Journal of Teacher Education, 44(4). https://doi.org/10.14221/ajte.2018v44n4.2

Butler, D. L., & Winne, P. H. (1995). Feedback and Self-Regulated Learning: A Theoretical Synthesis. Review of Educational Research, 65(3). https://doi.org/10.3102/00346543065003245

Callender, A. A., Franco-Watkins, A. M., & Roberts, A. S. (2016). Improving metacognition in the classroom through instruction, training, and feedback. Metacognition and Learning, 11(2). https://doi.org/10.1007/s11409-015-9142-6

Carless, D. (2006). Differing perceptions in the feedback process. Studies in Higher Education, 31(2). https://doi.org/10.1080/03075070600572132

Carless, D., & Boud, D. (2018). The development of student feedback literacy: enabling uptake of feedback. Assessment and Evaluation in Higher Education, 43(8). https://doi.org/10.1080/02602938.2018.1463354

Dewit, I. (2019). Product-service system design, a synthesis approach. University of Antwerp.

Dewit, I., Jacoby, A., & Matthyssens, P. (2021). Design Preconditions for Product—Service Integration. Designs, 5(2). https://doi.org/10.3390/designs5020029

Dewit, I., Van Ael, K., De Roeck, D., Baelus, C., De Rijck, R., & Coreynen, W. (2018). PSS Design and Strategic Rollout: tools for product-service systems (I. Dewit (ed.)). University Press Antwerp (UPA). https://www.aspeditions.be/nl-be/book/product-service-system-design-product-service-system-strategic-rollout/15791.htm

Gamlem, S. M., & Smith, K. (2013). Student perceptions of classroom feedback. Assessment in Education: Principles, Policy and Practice, 20(2). https://doi.org/10.1080/0969594X.2012.749212

Gan, M. (2011). The effects of prompts and explicit coaching on peer feedback quality. The University of Auckland.

Goossens, M., & De Maeyer, S. (2018). How to obtain efficient high reliabilities in assessing texts: Rubrics vs comparative judgement. Communications in Computer and Information Science. https://doi.org/10.1007/978-3-319-97807-9_2

Gray, C. M. (2013). Informal peer critique and the negotiation of habitus in a design studio. Art, Design and Communication in Higher Education, 12(2). https://doi.org/10.1386/adch.12.2.195_1

Habermas, J. (1978). Knowledge and Human Interests (2nd ed.). Heinemann.

Hattie, J. (2009). Visible Learning: A synthesis of over 800 meta-analyses relating to achievement (1st ed.). Routledge.

Hattie, J., Gan, M., & Brooks, C. (2016). Instruction Based on Feedback. In R. E. Mayer & P. A. Alexander (Eds.), Handbook of Research on Learning and Instruction (2nd ed.). Routledge. https://doi.org/10.4324/9781315736419

Hattie, J., & Timperley, H. (2007). The power of feedback. In Review of Educational Research (Vol. 77, Issue 1). https://doi.org/10.3102/003465430298487

Jones, I., Swan, M., & Pollitt, A. (2015). Assessing Mathematical Problem Solving Using Comparative Judgement. International Journal of Science and Mathematics Education, 13(1), 151–177. https://doi.org/10.1007/s10763-013-9497-6

Kluger, A. N., & DeNisi, A. (1996). The effects of feedback interventions on performance: A historical review, a meta-analysis, and a preliminary feedback intervention theory. Psychological Bulletin, 119(2). https://doi.org/10.1037/0033-2909.119.2.254

Laming, D. (2004). Human Judgment: The Eye of the Beholder. Thomson Learning.

Lattemann, C., Siemon, D., Dorawa, D., & Redlich, B. (2017). Digitization of the Design Thinking Process Solving Problems with Geographically Dispersed Teams. In Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and

Lecture Notes in Bioinformatics): Vol. 10288 LNCS (pp. 71–88). https://doi.org/10.1007/978-3-319-58634-2_6

Lesterhuis, M., Verhavert, S., Coertjens, L., Donche, V., & De Maeyer, S. (2016). Comparative judgement as a promising alternative to score competences. In Innovative Practices for Higher Education Assessment and Measurement. https://doi.org/10.4018/978-1-5225-0531-0.ch007

Luce, R. D. (2005). Individual Choice Behavior: A Theoretical Analysis (2nd ed.). Dover Publications.

Medola, F. O., Pavel, N., Baleotti, L. R., Santos, A. D. P., Ferrari, A. L. M., & Figliolia, A. C. F. (2021). Phenomenological Approach to Product Design Pedagogy: A Study on Students' Experiences in Interdisciplinary and Intercultural Settings. Design and Technology Education: An International Journal, 26(2), 86–100.

Nicol, D., & MacFarlane-Dick, D. (2006). Formative assessment and selfregulated learning: A model and seven principles of good feedback practice. Studies in Higher Education, 31(2). https://doi.org/10.1080/03075070600572090

Orsmond, P., Merry, S., & Reiling, K. (2002). The use of exemplars and formative feedback when using student derived marking Criteria in peer and Self-assessment. Assessment and Evaluation in Higher Education, 27(4). https://doi.org/10.1080/0260293022000001337

Pollitt, A. (2012). The method of Adaptive Comparative Judgement. Assessment in Education: Principles, Policy and Practice, 19(3). https://doi.org/10.1080/0969594X.2012.665354

Puryear, J. S. (2015). Metacognition as a Moderator of Creative Ideation and Creative Production. Creativity Research Journal. https://doi.org/10.1080/10400419.2015.1087270

Rittel, H. W. J., & Webber, M. M. (1973). Dilemmas in a general theory of planning. Policy Sciences. https://doi.org/10.1007/BF01405730

Schön, D. A. (2017). The reflective practitioner: How professionals think in action. In The Reflective Practitioner: How Professionals Think in Action. https://doi.org/10.4324/9781315237473

Shute, V. J. (2008). Focus on formative feedback. Review of Educational Research, 78(1). https://doi.org/10.3102/0034654307313795

Slovic, P., & MacPhillamy, D. (1974). Dimensional commensurability and cue utilization in comparative judgment. Organizational Behavior and Human Performance, 11(2). https://doi.org/10.1016/0030-5073(74)90013-0

Spooren, P., Mortelmans, D., & Denekens, J. (2007). Student evaluation of teaching quality in higher education: Development of an instrument based on 10 Likert-scales. Assessment and Evaluation in Higher Education, 32(6). https://doi.org/10.1080/02602930601117191

Thurstone, L. L. (1927). A law of comparative judgment. Psychological Review, 34(4). https://doi.org/10.1037/h0070288

Tovey, M. (2015). Design Pedagogy: Developments in Art and Design Education (1st ed.). Routledge.

Van den Bergh, L., Ros, A., & Beijaard, D. (2013). Teacher feedback during active learning: Current practices in primary schools. British Journal of Educational Psychology, 83(2). https://doi.org/10.1111/j.2044-8279.2012.02073.x

Van Gasse, R., Mortier, A., Goossens, M., Vanhoof, J., Petegem, P. Van, Vlerick, P., & Maeyer, S. De. (2017). Feedback opportunities of comparative judgement: An overview of possible features and acceptance at different user levels. Communications in Computer and Information Science. https://doi.org/10.1007/978-3-319-57744-9_3

Wiliam, D. (2013). Assessment: The Bridge between Teaching and Learning. In Voices From the Middle (Vol. 21, Issue 2).

Yin, R. K. (2016). Qualitative Research from Start to Finish Second Edition. In The Guilford Press. https://doi.org/10.1007/s13398-014-0173-7.2

A blended approach to design education through clinical immersions and industry partnerships in design for healthcare

Louise Kiernan, University of Limerick, Ireland
Eoin White, University of Limerick, Ireland
Kellie Morrissey, University of Limerick, Ireland

Abstract

Contemporary design education seeks to prepare students for the workplace through studio-based learning that replicates real world practice. Design problems in the workplace have become increasingly complex and one example of this is within the area of design for healthcare, which requires multidisciplinary collaboration between various stakeholders to build knowledge in order to create new products, services systems and spaces. The complexity of these roles creates challenges for design educators in preparing students for the workplace. This paper presents a hybrid approach to address this challenge by presenting a real-world approach to design education. This entails a bottom-up approach to facilitate design research in a clinical setting to gather rich insights and needs of the clinical setting along with a top-down industry collaboration with sponsored briefs to guide students through the requirements of developing solutions in a heavily regulated field. The paper outlines examples of this process and how it was achieved in a blended model that was predominantly online in response to the changed environment caused by the COVID-19 pandemic.

The advantages of this model are threefold, students gain deep knowledge and skills through collaborating with a variety of stakeholders within health care, they gain the opportunity to validate their designs through testing and feedback with these partners and lastly students develop the connections to create opportunities for further partnerships and employment.

Keywords

Real world practice, Design education, Design for healthcare, Clinical immersion, Industry collaboration.

Introduction

Design and healthcare

Due to the many challenges faced by healthcare such as ageing populations, chronic diseases and pandemics, providers are looking to the services of designers to help with reimagining healthcare. These services range from designing medical devices and medical charts, to designing medical services for tackling pandemics, and the layout of operating theatres (Fairs, 2020).

A study conducted by Kiernan and Ledwith (2014) showed that product design graduates believe that design education needs be more aligned to the demands of industry and facilitate them with flexible and transferable skill sets to take advantage of the evolving role of the designer. Further criticisms labelled at design education is that few schools are adopting the trend towards interdisciplinary teamwork that takes place in industry and that design students are not well prepared with the knowledge and skills required for employment when they graduate (Medola et al., 2021; Yang et al., 2005). It has also been shown that there is no great link between design practice and design education (Gajendar, 2003; Roald, 2006).

Bhavnani et al. (2017) argue that the transformation of Healthcare requires collaboration and a shared vision between various stakeholders to create models that are primarily patient-centered. Fry (2019) argues that co-creation and multidisciplinary teams are necessary in the design of healthcare products and services and advise an iterative, user-centered and holistic approach that considers the patient experience. They state co-creation with all stakeholders can challenge the hierarchy and silo-mentality that is ingrained in many healthcare organisations.

The role of the designers has changed and this in turn poses further challenges for Design education. Park (2020) proposes five skills that designers can bring to developing solutions in healthcare:

1. Problem solving and the ability to deal with ambiguity;
2. Communicate skills to understand the needs of others and to communicate solutions;
3. Empathy for those who may be anxious or suffering from chronic illness;
4. Ability to co-create with users and multiple stakeholders; and
5. Creativity in challenging conventional solutions with blue-sky ideas.

Traditionally design education has focused on studio-based learning that follows the master apprentice role. It is clear that student designers must be afforded the opportunity to leave the studio and collaborate with the stakeholders and experts within the subject field to fully understand the complexities of the problem before they can develop solution. In turn, they need to be able to validate proposed solutions with the same stakeholders and experts.

This paper describes a blended studio-based and online design curriculum, which uses both clinical immersion and industry collaboration to facilitate real-world-based design skills acquisition and experience. Two case studies are then presented which describe the bottom-up learning approach of clinical immersion and the top-down approach of industry collaboration. Clinical immersion is a bottom-up approach as it involved the application of design research by student designers to uncover a range of unmet needs to provide opportunities for innovation, while the top-down approach of the industry collaboration requires students to design solutions for specific, already identified needs, and then validate those solutions. These approaches were used in conjunction with in-house design challenges to triangulate different experiences, ultimately enhancing industry-relevant skill acquisition, expectations, and experiences.

Studio based and online learning

Studio based learning has many advantages mainly due to face-to-face interactions between students and teachers in a master apprentice type model (Yorgancıoglu & Tunalı, 2020). There are concerns with regard to this model of education as Product design pedagogical approaches require different competences knowledge and perspectives, that demands the input of expertise from fields outside of design (Medola et al., 2021). However, in the traditional model of design education there are concerns that the acquisition of knowledge is limited and based on the personal experiences of one discipline which may be disconnected from real design problems which has been reported to hinder students motivation and engagement (Rodriguez et al., 2018). It has also been shown that an overly teacher-centred studio environment may hinder the ability to carry out group work, research activities and the development of critical thinking skills (Yorgancıoglu & Tunalı, 2020). Medola et al. (2021) argue that immersive experiences that provide human interaction and engagement with immediate real-life feedback are the key elements of constructivist learning to facilitate real world problem solving. The involvement of multidisciplinary specialists and end users, can facilitate collaborative and active learning in the solving of today's complex design problems (Seidel & Godfrey, 2005). There have been calls for design educators to create the environment to teaching designers to function in multidisciplinary teams emphasising the complex process of inquiry, learning and decision making (Dym et al., 2006). These real world experiences can be created by building links with industry to partner on design briefs (Breitenberg, 2006; Harriss & Widder, 2014) as industry problems are very different from the types of problems normally used in education (Jonassen et al., 2006).

Due to the recent pandemic the teaching environment has shifted to online. While there are advantages to a virtual design studio, to create a forum for collaboration there are also disadvantages. The virtual studio has some advantages and can provide a forum for highly interactive engagements in a timeless and flexible manner (Niculae, 2011). The virtual environment can facilitate flexibility in learning styles to allow students to work at their own pace (Fleischmann, 2020). It can foster knowledge building, independence and efficiency in file sharing and project management (Rodriguez et al., 2018).

However there are drawback to relying solely on online learning, and many researcher point to restrictions in peer learning amongst other factors (Iranmanesh & Onur, 2021). There are potential issues for students to be able to meaningfully interact sufficiently to receive feedback, critique and support (Alnusairat et al., 2020; Tuckman, 2007). Students can also feel unsupported and become disengaged from the online studio experience (Alnusairat et al., 2020)

A number of researchers propose a blended design studio that combines the traditional physical studio with a virtual model (Iranmanesh & Onur, 2021; Saghafi et al., 2012). Further to this Rodriguez et al. (2018) advocate that a blended approach which combines, the conventional studio, a virtual studio and live projects, in order to promote effective collaborative learning at different levels and via diverse means.

Methodology

The paper presents a reflective analysis of data gathered through an MSc in Design for Health and Wellbeing around two projects carried out. The first project entailed a clinical immersion in several hospital to observe maternity and gynaecological clinics. The second project involved a collaboration with a medical device company to develop solutions for a Laser Lithotripsy device. The sources of data are listed and described in Table 1.

Table 1: Description of data sources

Data source	Description	Number/ duration
Process books	Students' documentation of their research and/or design process, comprising text and visuals (sketching, CAD, or prototyping as appropriate) – ranging from 30-100 pages (submitted as a PDF), created over one 8-week period and one 4-week period, and collected at the end	25 (11 clinical; 14 industry)
Reflections	Students' written reflections and feedback, submitted at various stages of the projects	12
Recorded and transcribed feedback of presentations to clinical and industry partners	Students frequently met with both clinical and industry partners during each project, and in several cases fed their project findings back to them via video meetings in order to receive feedback; these were recorded and transcribed	4 hours

In analysing the above data, a process of inductive analysis informed by reflective thematic analysis approaches was applied (Braun & Clarke, 2020), as it has been used as a method to organise and explore both students' coursework (Semb, Kaiser, Andersson & Sundborn, 2014), as well as to analyse varied data corpora (Deighton-Smith & Bell, 2018). To do this, each author read the data sources thoroughly, with two authors then assigned to each student project to improve inter-coder reliability. Both pairs of authors used a procedure of coding with close reference back to original data. A final round of categorisation sorted our second-round codes into themes. We finalised our themes during a final meeting among all co-authors. Not all themes emerged in each project and Table 2 shows, which themes corresponded to each of the projects:

Table 2: Description of data sources

Themes	Clinical immersion	Industry partnership
Understanding how to conduct design research	x	
Empathy and user understanding	x	
Understanding Dignity and ethics	x	
Understanding ergonomic and human factor requirements	x	x
Student clinician/ industry partner engagement	x	x
Expert critique	x	x
Designing for real world constraints and requirements		x
Student reflections on the immersion experience	x	x

Findings

Findings from clinical immersion

The aim of an immersive experience is to identify design opportunities within a clinical setting. The students were immersed in a number of maternity and gynaecological clinics across five different hospitals in the South west of Ireland. The purpose of the immersion was to identify problems and needs associated with various aspects of the health care environment with the purpose of developing solutions in response to those needs. The students acquired hundreds of observations which were rigorously distilled to key needs. These were then progressed through ideation and concept development, and then validated by the maternity staff. Figure 1 outlines the immersion process.

Figure 1 The Immersion project process

Understanding how to conduct design research

Students attending the clinical immersion sites engaged in note-taking, which they later took home to scaffold their anonymised observational data. All names of the students were anonymised with pseudonyms. For many students, this was their first time carrying out field research in this manner, and they approached the process of documentation in slightly different ways, see Figure 2. Ian took the advice of the lecturing staff and created his own template printouts, which he used to structure his observations. He also took time to research the context and the different roles he might encounter. In writing up his background preparation, he reflected that certain things worked well - 'analysing potential stakeholders and sub-environments helped me focus on all aspects of the hospital environment' – but he would change some things based on the fast-paced nature of the clinics he attended:

> *"I would try reduce the amount of pages as it was difficult to turn through pages quick enough [and] I would change the overall layout of the observations document sheet as there is not enough time to document everything … I would put a bigger emphasis on sketching as it would again save time but also give a better visual understanding."*

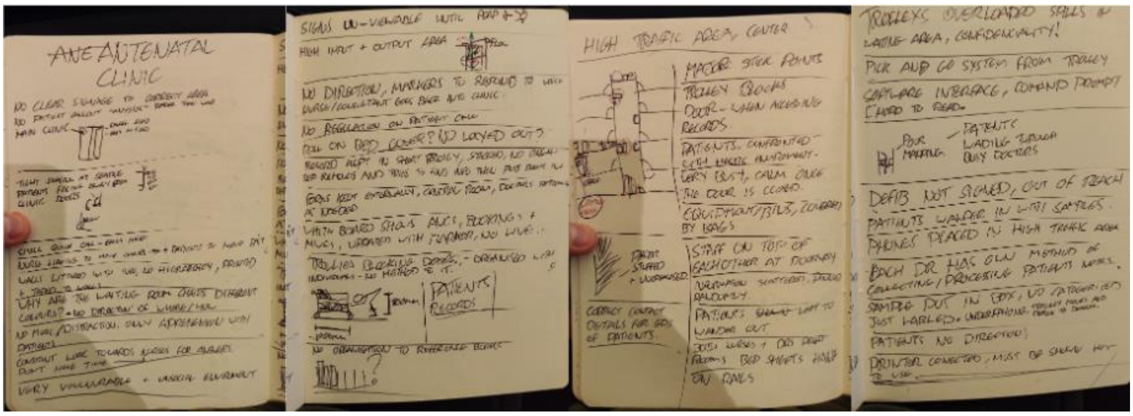


Figure 2: field notes examples

Following the immersion clinics, the student continued to collaborate with tutors peers and clinicians online. Miro and Teams were used to facilitate online collaboration. Students collaborated in real-time with one another. The online platforms allowed:

- The uploading of physical sketches & prototypes and sketching
- Students and tutors to annotate and comment on work
- A repository of work
- A forum for presentation to the external partners

Figure 3 is an example of a Miro board:

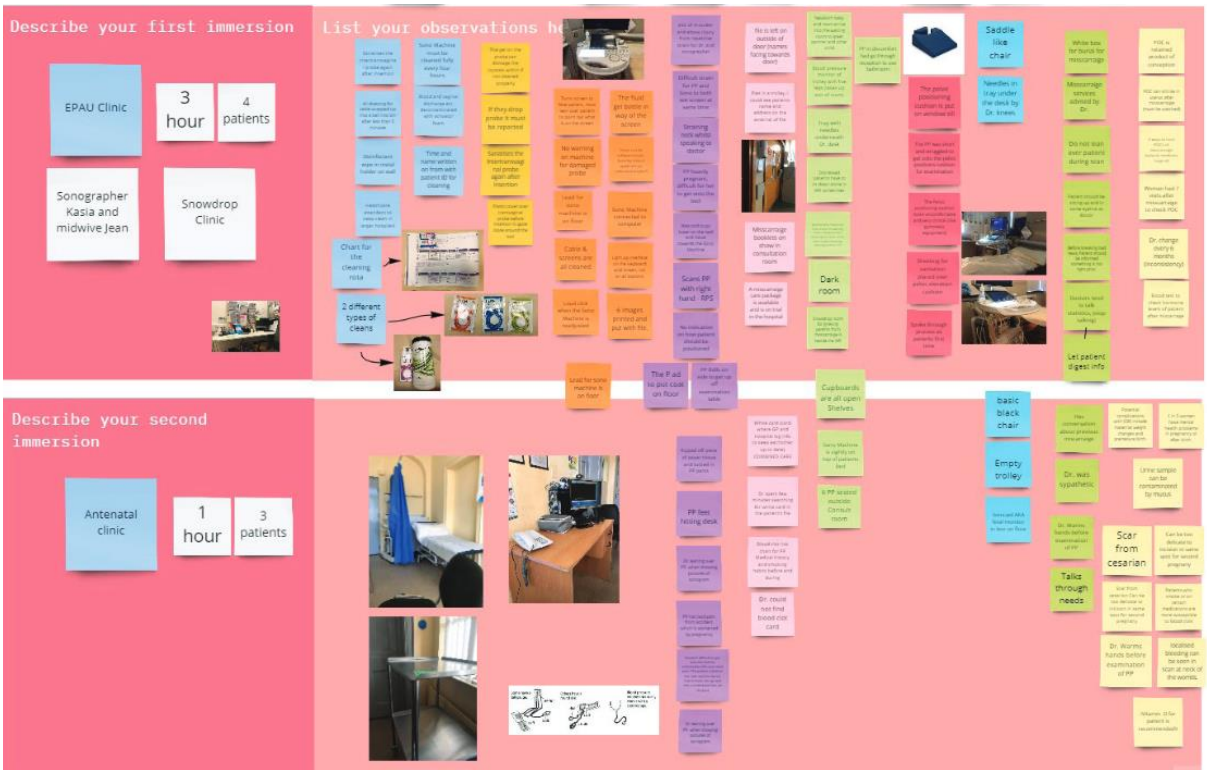


Figure 3: Miro board example

Empathy and user understanding

Designers are required to empathise and design for the needs of their users and all stakeholders. The immersion experience gave the students the opportunity to put themselves into the shoes of others (Kouprie & Visser, 2009). During their clinical immersion, many of the students were cognisant that they were witnessing procedures and other clinical experiences that may be uncomfortable or even distressing/traumatic for some patients. This is evident in Rachel's field notes, who reflects on the insufficiency of the designed space for patients dealing with trauma:

> *"The space in the EPU [early pregnancy unit] is not patient focused. Many patients that come in are suffering miss carriage [sic] and the space used doesn't give them privacy or a place to come to terms with the news."*

Similarly, Dana's field notes, pay particular attention to the need for patients undergoing difficult procedures to also be comforted by staff:

> *"Patient wanted to be comforted but nurse was busy – the patient was nervous and squeamish making the procedure harder. Nurse couldn't hold the patient's hand due to electric shock – the patient was upset that her hand wasn't held at the point she needed it most."*

Understanding Dignity and ethics

Some students noted issues surrounding dignity, fairness and overall ethics at their immersion sites.

One student observed a clinician who had to order her PPE at her own expense – as a hijab wearer; the PPE provided by the healthcare system did not meet her needs regarding head coverings.

Many students were struck by the compromising of patients' dignity during often-difficult times:

> *"Patients were uncomfortable removing clothing in scan room, as anyone, including the public could enter the room."*

Understanding ergonomic and human factor requirements

Many of the students noted an ill fit between the environment and equipment provided in the clinical immersion sites. This extended to both cognitive and physical aspects of the environment. One student observed issues around placing patients in the correct position for clinical examinations and developed solutions accordingly, see Figure 4.

Figure 4: Examples of solutions around ergonomics in positioning of patients

These observations around the 'fit' of the user to the equipment continued into the operating theatre, where students noted that such discrepancies might have dangerous consequences.

One student identified issues in the operating theatre:

> *"surgeon could not find the tray to change his gloves initially so he had to be shown by the nurse' and 'surgeon was unable to tie his apron so he had to get a nurse to pass him the ties to secure it."*

He notes several issues with shorter staff members who have to use 'steps' or assistance from a colleague to reach a patient's body in order to complete stitching.

During his immersion, Ian notes several constraints that arose, perhaps due to an interaction between anatomical difficulties and insufficiently well-designed equipment:

> *"The surgeon was finding it difficult to extract the fluid using the suction equipment as organs were in the way and it kept suctioning on to them… the surgeon had difficulty inserting the surgical tool through the port as both his hands were occupied and the port was moving around."*

Similarly, Jake identified concerns arising from difficult manoeuvres he witnesses during laparoscopy, and cites:

> *"a need for a method of cutting tissue and stemming blood-flow within a patient that causes minimal damage to surrounding tissue and is easily carried out from any position at the operating table by a single user."*

Student clinician engagement

Students' engagements with healthcare staff during the immersion led to their creating new ideas for products, services and systems that, had they not had the same interaction, they would not have noted as possible or relevant. Students also felt that it was important to maintain the links with the clinicians during the development phase of the project to validate ideas:

> *"I would also collaborate with a clinician to review the problems that I have developed to ensure that they are actually issues that need addressing and to confirm that they are accurate."*

Describing his engagement with Dr Ng during his time in the hospital, Dave noted that Dr Ng was 'happy to take any questions' during times when patients were not in the room – in particular, Dr Ng provided Dara with 'some medical brochures on the Harmony Prenatal Test [and] links to websites' This information provided to Dara later becomes the basis for his design proposal around sex disclosures in prenatal testing.

Describing his own experiences in the clinical setting, Wayne similarly credits the interaction with clinicians as 'essential':

> *"Discussing with them allowed two essential things, to understand precisely their work methodology, but also to ask them what they saw as the problem with their work. That is how I became aware of the obvious problem of the positioning of the oxygen balloon, which on the new machine does not have a telescopic arm to give the nurse the possibility of working in a pleasant position. All these may seem to be just details, but together they create a field of possible improvements."*

Expert critique

Finally, clinicians' engagements with students on an ongoing basis through the MSc was important not just because, as mentioned above, it fleshed out their anatomical knowledge, but because, together, interaction with the clinicians helped the students to incrementally scope out the burgeoning design spaces emerging through their work. This was achieved in a dialogical manner, with students presenting their design work to clinicians and then engaging in a process of questioning and answering. The following is an example from a later presentation to clinicians where the student, Phillip, is presenting a mechanism that would operate inside the uterus:

Dr Shone: "So basically you're saying there's a sheet in which the silicone goes in and it takes the shape of the hole inside of the cavity. So at the end of the - you know, the balloon - will it not come out, will the gel will not fall out?"

Paul: "You can set that the shape of the balloon by whatever [way] you choose so you'd have a pre-set shape that would be cured to that shape."

Clinician's participation was not just isolated to asking and answering questions, they suggested new possibilities for design ideas around which students had only just begun to ideate. For instance, in reviewing Dara's design work, Dr G. levies some potential shortcomings of the idea, before suggesting refinements to the form:

"You could do it like an M shape but a little bit at the top instead of bringing it down - so that you can look at the size of the, you know, uterus and put it up there rather than it going in the middle. Therefore, in the middle - it can be at the top, that way it might be good. I like that - when you put it in and you just retracted out. That was really good. Yeah. Excellent."

Figure 5: Dave's early prototyping around IUD deployment

Student reflections on the immersion experience

Overall, the students found the experience to be rewarding

"I felt that the immersion was a very worthwhile experience and really broadened my understanding of the process of immersion as a method of research that I could use in my masters design project and further projects throughout my career."

"The entire experience of the immersion, findings synthesis and filtering process was very enjoyable and I gained a great understanding and perspective of how the research process works and how healthcare workers operate."

The process is much nuanced and takes practice and the following reflections highlights how the students learned to appreciate and acquire these skills.

> *"Seek to observe people, procedures and not focus from the outset on the medical products used.-Avoid thinking about solutions right away when I have only defined the problem.- Not to think that an observation is not worth noting. All these details will enable me to be more efficient during the second half of the year to help me design a solution for the speculum in the best possible way"*

> *"All my observations should therefore never be biased by my opinions and always be as factual as possible. I should constantly avoid the: "I think that" to always go towards the "I saw that" or "the medical professional told me that". It was essential to follow this path in order to avoid misinterpretations."*

Students' engagements with clinicians were critical in clarifying the bounds of their anatomical knowledge: although they had taken a 15-credit module in Anatomy and Physiology, their design ideas were sometimes more speculative than grounded.

> *"I didn't expect to discover so much in so little time. It should be noted that the help of the nurses and doctors in answering my questions and giving me feedback was key."*

Later, presenting his work on a IUD 'introducer', Jack receives the following question from a clinician specialising in robotic gynaecology:

> *"My question is that, how does this thing locate the exact orifice? And then suppose - the orifice is not always open, and sometimes you have to dilate it and it can be, you know, even when we are dilating, we can even perforate it as well."*

When Jack explained that he had not had time to research dilation methods, the clinician responds:

> *"It can be done if you have a, like, suppose for example, laryngoscope - when they do it and they have the camera on it."*

In this way, interaction with clinicians helped students both understand the bounds of their design space, as well as encouraging the student to continue the work by instructing by example reference to another, likely more common, procedure, laryngoscopy.

This section has described some of the analytic findings regarding student's engagements during their clinical immersion, as well as in presenting their design work (originating in the immersion) to clinicians later through the year. In doing this, students naturally attended to issues of empathy, ethics and ergonomics; used different documentary and reflective methods; and collaborated with consultants not just to gain new knowledge, but also to shape and refine the design space in which they were working.

Findings from the Industry partnership experience

The industry collaboration project involved a four-week project with a medical device company. A brief was co-drafted by the company and the tutors involved in the project. The collaboration with industry partner involved a two-hour on-line kick off meeting to gain a contextual understanding of the requirements in week one and then an online four-hour presentation feedback session with the industry partner in week three. Feedback from the presentation were then incorporated into a final deliverable in week four, which were then sent to the industry partners. Figure 6 provides the project processes

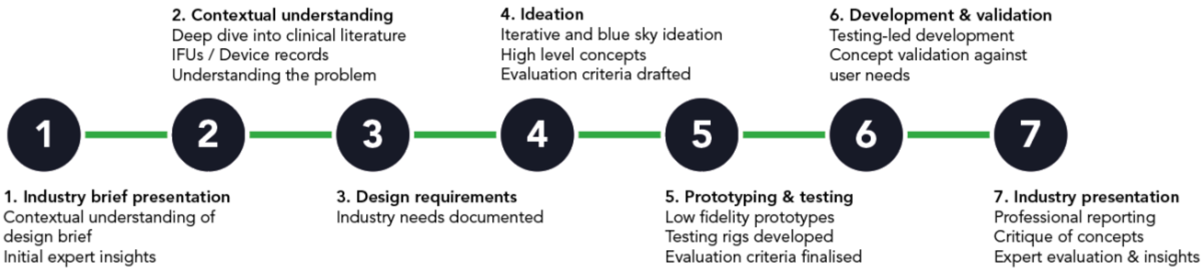


Figure 6 - Industry collaboration project process

Laser lithotripsy project

The design challenge was to design a urethra scope which would allow a physician to adjust laser beam settings during lithotripsy, eliminating the need for assistance from a second person. In advance of the meeting with the industry partners, each student was supplied with a brief, to prepare questions for the subsequent industry partner meeting. The industry partner meeting allowed the students to ask questions and become more acquainted with the context of use of the device, as well as to define specific design goals.

Understanding ergonomic and human factor requirements

From the initial meeting with the company, the students learned that the main focus of this project was in the area of human factors and entailed improving a product to make it easier to perform a procedure without the need for assistance to change settings and controls during use in the operating room. While the brief supplied the students with high-level background information, the students ultimately led their own knowledge acquisition activities. This empowered them to conduct a deep dive into the secondary literature, to examine the commercial landscape of similar products. Competitor analysis also helped to define and prioritise the design requirements in further detail to the brief. Concepts were ideated through brainstorming sessions, low fidelity mock-ups, and user testing, prior to being developed further. Design tools such as sketching were used in early-stage designs but were quickly migrated to digital programs like SolidWorks or Adobe Illustrator for functional detailing and product storyboards, prompting students to be flexible in the media through which they could communicate their ideas, see Figure 7.

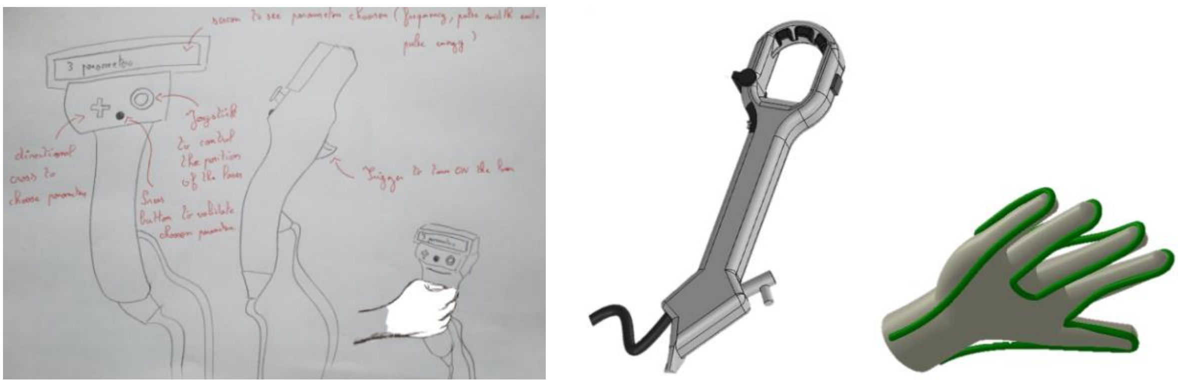


Figure 7: communication media examples

Low fidelity models were also created along with mock-ups of the clinical environment and surrounding equipment so students could test their ideas quickly, discarding those which did not fulfil the brief. This part of the project required students to think creatively, utilising workarounds and readily available materials in order to create a means of verifying the function of their concepts, without resorting to high-fidelity manufacture or in situ testing. These quick-and-dirty prototypes displayed how a solution could demonstrate promise without the need to resolve every detail. Once tested low fidelity models were replaced by 3D versions for final testing, see Figure 8.

Figure 8: Comparison of low-fidelity prototype versus final result. Note the change in design and prototyping methods to account for functional usability and validation as the project progressed.

Mocking-up the clinical environment also demonstrated how concepts could be used in conjunction with the already existing infrastructure, enhancing the overall product development, see Figure 9.

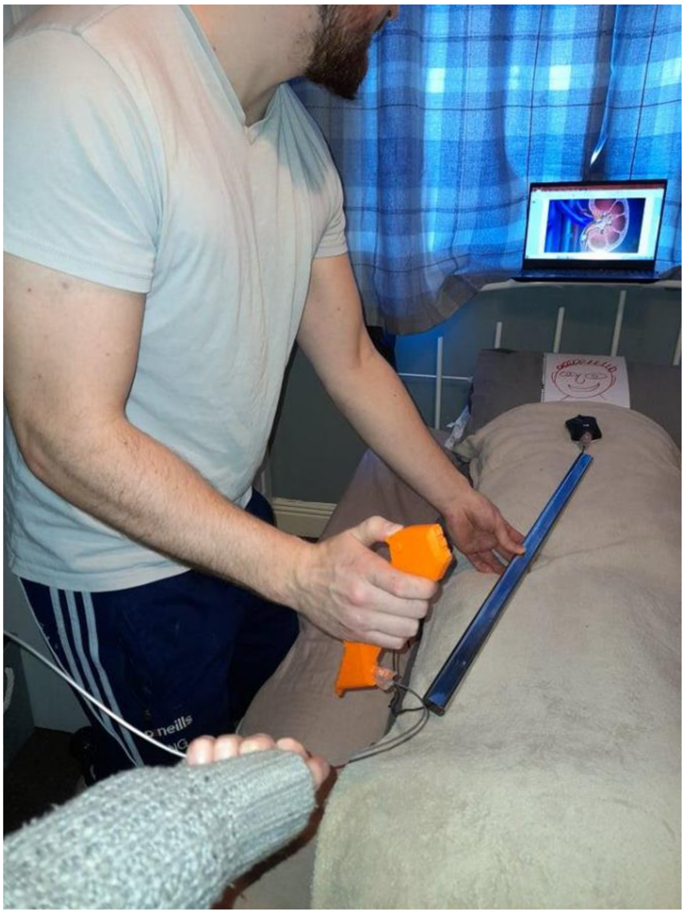


Figure 9 - Students created their own testing environments to enhance their understanding of in situ operation of the device, and to robustly validate their concepts.

Design considerations such as handle articulation, button positioning, and usability/human factors could then be validated robustly using these environments to control external factors which could potentially impact the validation results. Prototyping also helped to communicate and confirm the design solution with the industry partner:

> *"Nice job on the test rig in particular. I really appreciated you going to the point of actually having the screen and actually pushing a mouse towards the kidneys. It was a nice test environment"*

Student industry partner engagement

The Industry collaboration was also beneficial for the company. While reflecting on the projects, a member of the industry team commended the students on their novelty and stated that they intended to progress several of the ideas further to more robustly validate them and determine their commercial viability. It was clear that the students brought fresh insights to the project.

> *"I think it's some really good work and some really, you know, out of the box ideas; definitely ideas there that we wouldn't have thought of, and the presentations will be really useful because... ...there are some really good ideas that I think we might want to talk about how we could you know progress them."*

Expert critique

Expert critique was very welcome, as the deliverable for the brief was a developed concept as opposed to a final solution. In a real-life industry setting, the questions posed by the industry partners would naturally be asked at this point, prompting further development, redesign, and more robust design validation. Both the students and industry partners knew that it would be impossible to account for all risks; however, this expert insight gave the students a snapshot of the real-world equivalent of this stage in the design process, enhancing their overall experience of the project, rooting it in industry-relevant rigour, and signposting to further design development opportunities.

Designing for real world constraints and requirements

When presenting the outputs of this project back for expert insight and feedback from the industry team, the questions posed by the industry team also prompted the students to consider aspects of their solutions that were not previously identified as particular risks, or potential points of failure for their designs.

> *"I would have concerns over the cleanability of that, if there were any fluids around that nylon strap."*

Some questions posed sought to ensure that the solutions proposed by the students were routed in rigorous design choices, which were fully accountable across the entire scope of the project. Some questions also indirectly identified risks, which would also prompt further development in order for them to be mitigated.

> *"When you were considering the button placement at the top of that internal circle area, your reasoning behind having them together, and knowing which one you're pressing, how does the user know that? And did you consider spreading them out more, or was there are a reason for why they were at the top?"*

Student reflections on the industry project

Students got rigorous experience of the reality of industry-based R&D, which is quite fast paced, and results focused. They honed their skills that industry values, while also using their design skills to fully understand the requirements and deliver a solution in a short time, sometimes delivering solutions which, although were unconventional at times, still answered the brief.

> *"I found it hard to identify objects which would be good to prototype with but I am happy with what I produced. Particularly in the short time frame." Quote from MSc student*

These projects by nature also empowered our students to engage in an industry-orientated design project, while also naturally building in risk assessment and mitigation in tandem with the design process, which are important when considering the design of a product with the intention of placing it on the market.

> *"I enjoyed doing the additional risk assessment, to identify potential risks for this product. I think I made some good considerations for how this solution fits into the*

environment it will be used in." Quote from MSc student regarding the value of risk assessment

There were some challenges also expressed by the students. The short time frame and steep learning curve was demanding. Students were required to utilise their resources effectively and collaborate with their peers for support as follows:

"I organised some teamwork brainstorming with a colleague when I was feeling overwhelmed by the brief which was extremely helpful." Quote from MSc student

The students all found it difficult to gather sufficient information to get the full requirements of the project. While they relied on video footage to observe the process, an immersion experience as conducted at the maternity clinics would have supplied more detailed insights. Students were also not able to gain access to cad files or drawings for the current product as the minute details were viewed as trade secrets, purposely kept from public domain. This limitation was referenced by the students; however, they were still able to design within the scope of research they had obtained.

"I found it challenging to find information. I presume this is because documents relating to the design of these documents are confidential. I would have liked to speak with engineers and other designers to understand how the original device worked." Quote from MSc student

The industry collaboration encouraged the students to readily engage with an industry-relevant project with the intention of delivering a functional solution that has real world implications. Access to expert insight as well as the milestone timelines also empowered the students to consider the project deliverable beyond the basic design challenge and to determine how to develop a feasible solution, which could evolve to a point where it is market ready. This type of experience ensures that students prioritise their skills development so that they are industry-relevant. It also expose them to the realities of designing within an industry context, where results matter most. Some challenges were realised such as the steep learning curve in a subject domain and the gaining of access to drawing files but overall the students found the project to be a rewarding learning experience.

Discussion

This article investigates a pedagogic approach that facilitated students to gain real word experience with live projects during the process and external collaborations facilitated by design tutors. The findings highlight that these projects created innovative learning activities that stimulated and maintained student engagement and motivation at different levels. Design problems are highly context specific, require access to specific domain knowledge (Jonassen & Hung, 2015). As highlighted by (Gill, 2021) pedagogy is impeded without the appropriate content knowledge. An important means of acquiring knowledge is by engaging with experts (Deken et al., 2012). These projects created opportunities for knowledge acquisition in a specific domain through the processes of expert engagement and observations.

The project themes varied in nature to expose the students to the adaptive aspects of the design process. The immersion project was predominantly a divergent phase where students to explored needs to provide opportunities for innovation in a ground up approach while the industry collaboration was predominantly a top down convergent phase in the project where specific and at times conflicting requirements had to be consolidated through a process of design, test, evaluate and iterate. This provided two very complementary yet varied experiences for the students.

During the immersion project the students gained the opportunity to speak to experts in a domain that was outside of their own field of design and as advocated by Medola et al. (2021) these are the types of experiences that are the key elements of constructivist learning. Throughout the project, the students gained the skills to carryout research in a clinical environment by observing clinics and procedures in the operating room and interviewing staff members. They also experienced the challenges of documenting the observations to provide the needs that would form the basis of the research. The increasing importance of empathy and understanding of the user in the design process is a key feature of human centred design (Barnes & Du Preez, 2015) and a key aspect of gaining empathy is through immersion within the context of the stakeholders involved (Thomas & McDonagh, 2013). The students provided a variety of accounts that related to issues where the perspectives, dignity and ethical needs of the patients were often overlooked.

The industry collaboration acquainted the students with the realities of designing within industry; the students were provided with many specific constraints for the project and were provided with feedback that was specific to those real requirements. Many of these requirements were around function, human factors, user and patient experience. Design validation skills were honed as students built their own testing rigs to both verify the functionality and validate that the solutions ultimately answered the challenge. A key component of this project was that students presented their refined concepts back to the industry collaborators for review. They received expert critique and insights, which would not be possible otherwise. This was most notable when projects deviated from or overlooked one of the requirements or constraints. While the tutors had knowledge related to design, they did not have the same oversight of the clinical and situational expertise of the partners and were not in the position to provide the detailed critique the students received.

Schön (1987) encourages reflection-on-action by the designer, during the design process to evaluate the project process so that improvements can be made to future projects. Gill (2021 p, 9) states that as well as evaluation of the process it is necessary to evaluate oneself to include "reflection on one's own methods, behaviour, beliefs and development."

It was important that there was mutual benefit to the partners on the programs otherwise, the continuation of such collaborations could not be sustained. As shown by (Gill, 2021) learning between novices and experts can be a two way process. In both projects, the experts expressed the benefit to them. The clinical staff in the hospitals were provided with insights from a fresh perspective to an already familiar environment and were provided with not only possible solutions to enhance patient care but also the expertise to bring elements of the design process to improve their own practices. The industry experts acknowledged that they showed aspects of design fixation, defined as a rigid adherence to a set of ideas or concepts, which can limit the scope for alternative ideas. (Jansson & Smith, 1991). The student design solutions they stated gave them fresh ideas that they had not considered.

Limitations & Future Work

While this paper presents some deep insights into conducting collaborative projects with external partners, the findings are based on content from student course work, recordings from meetings and reflections that were a part of the project. Further studies in the form of surveys and interviews could capture in more detail the student experiences to identify how the learning experience could be enhanced further. Formal interviews with the external partners could also provide further insights into how the engagement might be further improved.

Conclusions

When designing for healthcare, students must be afforded access to the clinical or health care environment to gather the design requirements through close observation and engagement with all stakeholders. Industry-relevant skill acquisition should be the goal of all design education so that students can appreciate the real world requirements and constraints of industry set projects. A Hybrid-approach as described in this paper enhances active and constructivist learning principles and encourages reflection through expert engagement and critique. Multiple experiences enrich the delivery of design education, but also builds the knowledge of the tutors and enables them to determine emerging skills that need to be taught. Finally, these collaborations also created opportunities for further partnerships and employment.

References

Alnusairat, S., Al Maani, D., & Al-Jokhadar, A. (2020). Architecture students' satisfaction with and perceptions of online design studios during COVID-19 lockdown: the case of Jordan universities. Archnet-IJAR: International Journal of Architectural Research.

Barnes, V., & Du Preez, V. (2015). Mapping empathy and ethics in the design process.

Bhavnani, S. P., Parakh, K., Atreja, A., Druz, R., Graham, G. N., Hayek, S. S., Krumholz, H. M., Maddox, T. M., Majmudar, M. D., & Rumsfeld, J. S. (2017). 2017 Roadmap for innovation—ACC health policy statement on healthcare transformation in the era of digital health, big data, and precision health: a report of the American College of Cardiology Task Force on Health Policy Statements and Systems of Care. Journal of the American College of Cardiology, 70(21), 2696-2718.

Breitenberg, M. (2006). Education By Design: Interdisciplinary Innovation. ICSID IDA. Retrieved 07/01/2010, from http://www.icsid.org/education/education/articles185.htm

Deken, F., Kleinsmann, M., Aurisicchio, M., Lauche, K., & Bracewell, R. (2012). Tapping into past design experiences: knowledge sharing and creation during novice–expert design consultations. Research in Engineering Design, 23(3), 203-218.

Dym, C., Agogino, A., Eris, O., Frey, D., & Leifer, L. (2006). Engineering design thinking, teaching, and learning. IEEE Engineering Management Review, 34(1), 65-92.

Fairs, M. (2020). Lack of design input in healthcare is putting both patients and doctors at risk, says physician. Retrieved 30th April, 2020, from https://www.dezeen.com/2020/04/21/design-input-healthcare-risk/

Fleischmann, K. (2020). Online design education: Searching for a middle ground. Arts and Humanities in Higher Education, 19(1), 36-57.

Fry, K. R. (2019). Why Hospitals Need Service Design. In Service Design and Service Thinking in Healthcare and Hospital Management (pp. 377-399). Springer.

Gajendar, U. (2003, August 10-12). Taking Care of Business: A Model for Raising Business Consciousness among Design Students IDSA National Education Conference, New York.

Gill, D. D. (2021). The Reciprocal Nature of Pedagogical and Technical Knowledge and Skill Development between Experts and Novices. Design and Technology Education: an International Journal, 26(2), 46-65.
Harriss, H., & Widder, L. (2014). Architecture live projects: Pedagogy into practice. Routledge.
Iranmanesh, A., & Onur, Z. (2021). Mandatory virtual design studio for all: exploring the transformations of architectural education amidst the global pandemic. International Journal of Art & Design Education, 40(1), 251-267.
Jansson, D. G., & Smith, S. M. (1991). Design fixation. Design Studies, 12(1), 3-11.
Jonassen, D., Strobel, J., & Lee, C. (2006). Everyday problem solving in engineering: Lessons for engineering educators. Journal of Engineering Education, 95(2), 139.
Jonassen, D. H., & Hung, W. (2015). All problems are not equal: Implications for problem-based learning. Essential readings in problem-based learning: Exploring and extending the legacy of Howard S. Barrows, 1741.
Kiernan, L., & Ledwith, A. (2014). Is design education preparing product designers for the real world? A study of product design graduates in Ireland. The Design Journal, 17(2), 218-237.
Kouprie, M., & Visser, F. S. (2009). A framework for empathy in design: stepping into and out of the user's life. Journal of Engineering Design, 20(5), 437-448.
Medola, F. O., Pavel, N., Baleotti, L. R., Santos, A. D. P., Ferrari, A. L. M., & Figliolia, A. C. (2021). Phenomenological Approach to Product Design Pedagogy: A Study on Students' Experiences in Interdisciplinary and Intercultural Settings. Design and Technology Education: an International Journal, 26(2), 86-100.
Niculae, R. L. (2011). The virtual architectural studio—an experiment of online cooperation. Review of Applied Socio-Economic Research, 1(1), 38-46.
Park, T. (2020, 30th March, 2021). Why Healthcare Needs Designers. The health Care Blog. https://thehealthcareblog.com/blog/2020/01/28/why-healthcare-needs-designers/
Roald, J. (2006, May 10-12). Design Leadership 5th Nordcode Seminar:"Connecting Fields", Oslo
Rodriguez, C., Hudson, R., & Niblock, C. (2018). Collaborative learning in architectural education: Benefits of combining conventional studio, virtual design studio and live projects. British Journal of Educational Technology, 49(3), 337-353.
Saghafi, M. R., Franz, J., & Crowther, P. (2012). A holistic blended design studio model: A basis for exploring and expanding learning opportunities. Society for Information Technology & Teacher Education International Conference,
Seidel, R., & Godfrey, E. (2005, 26-30 September 2005). Project and Team Based Learning: An Integrated Approach to Engineering Education ASEE/AAEE 4th Global Colloquium on Engineering Education Sydney, Australia, .
Thomas, J., & McDonagh, D. (2013). Empathic design: Research strategies. The Australasian medical journal, 6(1), 1.
Tuckman, B. W. (2007). The effect of motivational scaffolding on procrastinators' distance learning outcomes. Computers & Education, 49(2), 414-422.
Yang, M., You, M., & Chen, F. (2005). Competencies and qualifications for industrial design jobs: implications for design practice, education, and student career guidance. Design Studies, 26(2), 155-189.
Yorgancıoglu, D., & Tunalı, S. (2020). Changing pedagogic identities of tutors and students in the design studio: Case study of desk and peer critiques. Art, Design & Communication in Higher Education, 19(1), 19-32.

Exploring How Degree Apprentices Experience Their Engineering Identity Through Life Story Interviews and the Twenty Statement Test (TST)

Elena Liquete, School of Management, University of Bath
Elies Dekoninck, Department of Mechanical Engineering, University of Bath
Gina Wisker, School of Management, University of Bath

Abstract

Every year, around 35% of engineering graduates (mainly female and ethnic minority graduates) in the UK choose roles outside engineering. Given that engineering disciplines struggle to attract recruits, this represents a significant loss of qualified talent the profession can ill afford. A possible reason why engineers choose not to practise after qualifying may be that they have not developed a professional engineering identity during their engineering education. Research shows that engineering identity is an important indicator of persistence in both engineering education and the engineering profession. The purpose of this research is to gain a deeper understanding into the process of engineering identity formation in undergraduates studying for an engineering apprenticeship degree in England, with a view to proposing changes to engineering education that may better support the development of an engineering identity. A qualitative methodology is well-suited to the study of how engineering identity develops in engineering students, given that we are interested in the personal experiences of engineering students rather than in measuring standardised outcomes. This research is inspired by narrative inquiry through the use of life story interviews (LSI). This paper outlines the findings of a preliminary study with first and final year students. The findings presented are surprising in that they seem to indicate that the four years of a degree apprenticeship have little impact on students' identification with engineering. Going forward, engineering educators need to consider how the development of an engineering identity can be supported in engineering education.

Keywords

Engineering identity, engineering education, identity theory, degree apprenticeships

Introduction

Engineers are at the core of a country's economic success. They create the technologies that people want to buy, bringing wealth to their nations, and are well equipped to solve the problems facing the human race, from global warming to cyber security or water scarcity. The importance of engineering disciplines to the UK economy is well understood; in 2015, engineering generated 25% of the UK's GDP and employed 19% of the workforce (EngineeringUK, 2019). Although engineering graduates have excellent employment outcomes and earn 17% more than the average graduate six months after graduation, the profession struggles to attract recruits in sufficient numbers. This means that the UK has a shortage of engineers, threatening the country's ability to thrive in a globalized economy. However, the shortage of engineers is not just a problem in the UK; a 2019 report from the European Commission (McGrath, 2019) highlights the shortfall of skilled professionals in civil, mechanical, electrical and software engineering in the EU, Norway, Iceland and Switzerland. The global competition for engineering talent exacerbates shortages at the national level. EngineeringUK, a not-for-profit organisation aiming to increase the talent pipeline into engineering, estimates that in the UK, there are 200,000 fewer graduates entering engineering than are needed, with 46% of engineering employers reporting difficulties to recruit engineers. To make matters worse, not all engineering graduates develop their careers in engineering roles; a report from EngineeringUK notes that in 2018, of all the engineering and technology graduates who found jobs within 6 months after graduation, 34.7% of women and 36.2 % of ethnic minority graduates “were in roles that were neither engineering-related nor within the engineering sector” (EngineeringUK, 2019). This represents an important loss of qualified talent to the profession. Pierrakos, Beam, Constantz, Johri and Anderson (2009) have suggested that those graduates who pursue careers outside engineering did not develop an engineering identity during their studies.

In England alone, there are more than 1,100 undergraduate engineering degrees, offered by 150 providers (UCAS website) and although they focus on diverse aspects of engineering and meet different student needs, their curricula are remarkably consistent and primarily focused on the acquisition of technical knowledge, engaging learners “in highly structured, recipe-like” learning activities (McGowan & Bell, 2020, p. 982). This positivist approach to course design is based on the tacit understanding that knowledge is “hard, objective and tangible” (Nicholl, 2009, p. 22) and disconnected from the learners’ lived experiences (McGowan & Bell, 2020, p. 982). The prevalent positivist mindset in engineering education is reflected in the requirements of national and international accreditation bodies, who share a competency-based approach to engineering certification. This is not the case in other professions, where the development of a medical identity (Cruess, Cruess, Boudreau, Snell & Steinert, 2014; Jarvis-Selinger, Pratt & Regehr, 2012; Monrouxe, 2010) or a teacher identity (Beauchamp & Thomas, 2009; Gohier, Chevrier & Anadon, 2007) is an important part of the training for the profession. Could this be at the root of the problem in engineering? Is the lack of focus on developing an engineering identity damaging the profession?

Education in the UK is devolved to its four nations, so this paper will focus on engineering education in England, where there are two routes to qualifying as an engineer: an academic route via a university degree and a work-based route via an apprenticeship degree. Most European countries have apprenticeship schemes, such as Germany’s highly respected Vocational Education and Training System, in which apprentices spend part of their time at a company and the rest at specialist vocational schools. In the Netherlands, apprentices spend typically four days per week in the company and one day per week in “off the job” training whilst in Belgium they generally spend two days per week in training and three days per week at the company. In other countries, such as Sweden, apprentices divide their time equally between the classroom and the workplace (Armitage, Bourne, Di Simone, Jones & Neave, 2020). The students in this preliminary study are Product Design and Development apprentices studying two days per week for a BEng in Engineering and working three days per week in engineering teams for a technology company. In order to investigate how students develop their engineering identity during the four years of their education, this research will explore how first and final year students experience their engineering identity and the impact of their engineering identity on how they envision their future – inside or outside engineering disciplines.

Identity theory provides a useful lens for the study of professional engineering identity. If we believe that "Identities are the meanings that individuals hold for themselves – what it means to be who they are" (Burke, 2003, p. 196) then a methodology that uses the tools of social science to study personal meaning, such as narrative enquiry, seems well suited to the study of identity (Goodson & Sikes, 2001). This methodology is rarely used in engineering education, that tends to favour a quantitative paradigm, with few engineering educators trained in qualitative methodologies (McGowan & Bell, 2020, p. 1001). This paper proposes the use of narrative enquiry as a research method for engineering education and presents findings from an initial study using this method. The findings draw together new insights about how engineering students experience their engineering identity, thereby also confirming narrative enquiry as a valuable research method to develop understanding of this topic.

Identity in Engineering Education

Admissions processes for engineering programs tend to focus on finding candidates who are good at sciences, mathematics and physics in particular. However, the persistence of those candidates in the engineering profession is closely linked to their identities (Pierrakos et al. 2009). It is this link between engineering identity and persistence in the profession that we aim to test with our first hypothesis: students with a strong engineering identity are more likely to be committed to a future in engineering. Whilst formally all a student needs to become a professional is to graduate from the appropriate institution, as Costello's research shows, "a certified professional school graduate who cannot "walk the walk and talk the talk" will not seem like a true professional to others and will not be successful" (Costello, 2005, p. 23). Acquiring engineering knowledge and skills is clearly an important part of becoming an engineer but it is not enough; to become engineers, students must develop an engineering identity (Brickhouse, Lowery & Schultz, 2000). Many authors have looked at engineering identity, however, identity theory as a conceptual model has been largely overlooked when considering engineering student identity. This article seeks to address that gap. Identity theory is rooted in the work of the American sociologist George Herbert Mead (1934), who theorized that:

The self is something which has a development; it is not initially there, at birth, but arises in the process of social experience and activity, that is, develops in the given individual as a result of his relations to that process as a whole and to other individuals within that process. (p. 135).

This is to say that the self arises from social interaction. Blumer (1962) coined the term "symbolic interaction" to highlight that behaviours are symbols that carry meaning; what is important is not so much how we behave but how we and others interpret our behaviour. We operate within the structures in our society and our behaviour is shaped by those structures; this is what Stryker (1980) means when he refers to "structural symbolic interactionism" (SSI). Those structures include class, gender, ethnicity, profession, etc. Identity theory also draws on the work of William James (1890). Although James never actually used the word "identity", he talked about "multiple selves" in a way we would now understand as referring to multiple identities. He suggests that people have "as many different selves as there are different others that can recognize the individual" (James, 1890, p. 294). One can be a mother, a daughter, a wife, an engineer, a Christian, a volunteer, etc. depending on the different roles one plays in society.

Stryker and Burke (2000, p. 284) define identity as “the meanings that persons attach to the multiple roles they typically play in highly differentiated contemporary societies”. The basic premise of SSI is that identity emerges through interpersonal interaction and that these interactions are shaped by social structure; the social structure defines what behaviours are appropriate for each role. As we internalize those expectations, we are setting up the basis for our identity in that particular role. Stryker emphasized the role played by social structures in shaping human behaviour, recognizing the reciprocal nature of these relationships: “society shapes self, which shapes social interaction” (Stryker & Burke, 2000, p. 231). He defines identity as the “internalized positional designation” linked to each role a person has in society (Stryker, [1980] 2002, p. 60). He understands those positions to be relatively stable and built into the structure of a given society. Individuals within a society label each other and themselves, according to the positions they occupy, i.e., teacher, student, engineer. As individuals internalise those identities, they also internalise the meanings and behaviours that are expected of those identities, as well as the symbols and shared perceptions associated with an identity, in this case engineering identity. For engineering students, this means embracing the personal characteristics associated with the engineering profession, such as a logical approach to problem solving, attention to detail and tough-mindedness (Williamson, Lounsbury & Han, 2013). They must also be perceived as an engineer by their peers (Costello, 2009). This led us to construct our second hypothesis: students with a strong engineering identity are more likely to have person identities that support their role identity as an engineer.

A central premise in identity theory is that “people seek ways to establish and maintain those social situations and relationships in which their identities are verified” (Burke & Stets, 1999, p. 351). As engineering educators, we probably have a sense that this is the case in relation to our students and indeed, research shows that difficulties in verifying an engineering identity can cause students to abandon their studies (Pierrakos et al. 2009; Patrick, Borrego & Prybutok, 2018). Burke and Stets (2009) propose that identities operate as a continuous feedback loop, managing the meanings perceived in a given situation, with the objective of maintaining self-meaning within a comfortable range. When the perceived meaning (our interpretation of how others see us) matches our own self-meaning, our identities are verified. Identity verification leads to increased trust, commitment, and emotional attachment towards those who are verifying our identity and in turn, those feelings increase our sense of belonging to that particular group (Burke & Stets, 1999, p. 351). This is the theoretical basis for our third hypothesis: students with a strong engineering identity are more likely to have experienced trust in a formative relationship. A person’s identity becomes stronger when it is verified repeatedly. Lack of identity verification generates negative emotions linked to feelings of low self-esteem and low mastery (Cast & Burke, 2002).

The literature review presented above provides a general understanding of identity theory. Let us consider an individual engineering student as an example; she does well in her engineering studies, obtaining good grades and is in line to graduate with a first-class honours degree but, is that enough to validate her identity as an engineer? Academic achievement may not be enough, as being an engineering student invokes more than one single identity. Identity theory proposes that there are three different types of identities: role, group, and person identities. Burke and Stets (2009, p. 114) define role identity as “the internalized meaning of a role that individuals apply to themselves.” As different people will internalize meaning in a different way, the same role identity may have different meanings for different individuals. This is clearly the case in engineering, as there is a lack of clarity as to what it means to be an engineer. Group identity relates to how individuals identify themselves with a social group, in this case the engineering profession and finally, person identity is “the set of meanings that define the person as a unique individual rather than as a role-holder or group member” (Burke & Stets, 2009, p. 124). Going back to our engineering student, for her engineering identity to be validated she needs to see herself as an engineer, but she also needs others (classmates, lecturers, colleagues in the workplace, etc.) to see her as one. When someone validates our identity, we respond by generating trust in that person, and over time, this fosters greater commitment to the relationship (Burke & Stets, 1999). Identity verification of a role identity generates feelings of mastery and efficacy. Verification of a group identity generates feelings of self-esteem and integration (Burke & Stets, 1999) and verification of person identities generates feelings of authenticity.

Research Methodology

The researcher’s interest in the study of identity led her to explore life stories as a possible methodology for this research. Narrative enquiry, which uses personal stories as data, is well suited to the study of identity (Goodson & Sikes, 2001) and particularly since the 1990s, it has become a widely used methodology for “understanding the meaning of human experience” (Merriam & Tisdell, 2016, p. 34). In retelling their stories, individuals are constructing their identities (Chaitin, 2004). Life story interviews allow individuals to tell their life story in their own way, charting the path that has taken them to where they are today. Those stories are not set in stone; as we tell our stories, we choose what is important at a given point in time, in a particular setting and with a specific audience. Inspired by a narrative approach, the researcher undertook semi-structured interviews using a modified version of The Life Story Interview, an instrument developed in 1995 by Dan McAdams (2007) at Northwestern University, in which participants are interviewed about ‘the story of their life’ in the form of life chapters, key scenes, turning points, hopes, plans, challenges, etc. Students were asked to talk about: the path that took them to their engineering degree apprenticeship; their childhood interests and school experience; highs and lows of their time at the degree apprenticeship and their dreams and aspirations for the future. In narrative research, the relationship between the researcher and the researched has epistemological implications that shape the way in which the research is conducted, and this study is no exception (Patton, 1990). In this case, the researcher was known to the students as an employee at the institution providing the degree apprenticeship. However, her role was outside the students’ academic experience, and they could not expect to benefit from taking part in the research. The researcher’s coaching training helped to generate an environment of trust during the interviews, enabling students to speak at length and freely about their experiences.

To select participants for this preliminary study we used purposeful sampling, a technique widely employed in qualitative research in which researchers select a sample “from which the most can be learnt” (Merriam & Tisdell, 2016, p. 96). The researcher looked for participants who were willing to participate and were perceived to be good communicators by their Student Support Team, who knew them well. This is recommended by Palinkas (2015, p. 534), who highlights the importance of selecting research participants who have “the ability to communicate experiences and opinions in an articulate, expressive, and reflective manner”. Purposeful sampling requires in-depth knowledge of the individual students to be selected. The Student Support Advisors for each year group identified students who they felt may be interested to contribute to this research. Out of the shortlist provided, one male and one female participant from years one and four of the degree apprenticeship were randomly selected for interview for the initial study reported in this paper.

During the interviews, students talked at length about the path that led them to study engineering at degree level, the choices they considered, the people who influenced their choices and the process they followed before finally deciding to study engineering. However, during the analysis phase, it became clear that students do not think in terms of “identity” and that it was not obvious from the transcripts what other identities the students claimed for themselves. In order to gather more insights into this area, the Twenty Statement Test (TST) was used during a second, follow up call, asking research participants to complete the Twenty Statement Test (TST), a tool developed from a symbolic interactionist stance by Kuhn and McPartland (1954) to conduct empirical research on identity. When individuals think about themselves, they describe who they are by explaining what they do, how they do it and the values that locate them within a shared cultural frame. The TST explores the most salient aspects of the symbolic system that individuals apply to themselves (Rees & Nicholson, 2011). Research participants were asked to answer the question “who am I?” twenty times, or as many as they could come up with in a few minutes. All participants provided twenty statements, and their responses were analysed following Kuhn and McPartland’s guidelines (1954) which classifies responses as consensual or sub-consensual statements. They define consensual statements as “those which refer to groups and classes whose limits and conditions of membership are matters of common knowledge,” and sub-consensual as those “which refer to groups, classes, attributes, traits or any other matters which would require interpretation by the respondent to be precise or to place him relative to other people” (Kuhn & McParland, 1954, p. 69). Although the TST is not without its critics, this instrument has regained popularity recently in qualitative research due to “uniquely combining a structured approach with maximal response openness” (Rees & Nicholson, 2011, p. 88) and it was included in this study to gather more insights into the various identities of engineering students. Following Kuhn and McPartland’s approach to analysing the test results provided little light on the responses, and a second classification followed based on the three different types of identities defined by identity theory and explored earlier: role, group, and person identities.

Data Collection and Analysis

The Covid-19 pandemic and subsequent lockdowns and restrictions in England meant that interviews had to be conducted using MS Teams rather than in person. Research on the use of computer mediated interviews seems to indicate that they can be a “viable alternative to the face-to-face interview” (Curasi 2001, p. 372). The researcher feels confident that this research has not suffered as a result of having to conduct interviews online. What is harder to predict, however, is the impact that online teaching during the pandemic, and therefore reduced levels of personal interaction with classmates and faculty, may have had on the development of engineering identity for the class of 2020 and this is something that may need to be revisited at a later stage in this research. Four ninety-minute interviews with four students enrolled on the same engineering degree apprenticeship in England were conducted using a modified version of The Life Story Interview instrument (McAdams, 2007) a semi structured interview tool for life story research; two students were in their first year and two in their fourth and final year. In each year group, one student was male and one was female. Each video interview generated around seventeen pages of interview transcripts. Transcripts were analysed manually, reading them several times, seeking to reduce the data inductively, looking for themes in the different stories.

During the interviews, students talked at length about the path that led them to study engineering at degree level, the choices they considered, the people who influenced their choices and the process they followed before finally deciding to study engineering. However, during the analysis phase, it became clear that students do not think in terms of "identity" and that it was not obvious from the transcripts what other identities the students claimed for themselves. In order to gather more insights into this area, the Twenty Statement Test (TST) was used during a second, follow up call. Students were presented with a word document with the Twenty Statements Test and asked to complete it during the MS Teams call. The purpose of administering the TST in this way, rather than allowing students to complete it in their own time, was to elicit the most salient responses in the research participants. Although the form had twenty spaces, students were told to do as many as they could come up with; all four respondents completed the twenty statements.

Three out of the four undergraduates identified themselves with the engineering profession and saw their future as engineers; the fourth student was not so sure. Contrary to what may have been expected (Beam, Pierrakos, Constantz, Johri & Anderson 2009, p. 14), the students with a strong engineering identity already had it by the time they started their apprenticeship. The time invested in their degree apprenticeship, which includes exposure to an engineering workplace as well as academic study, only seemed to serve to clarify in the students' minds what aspects of engineering they enjoyed more than others. The fourth student started her engineering studies unsure about engineering as a career and remained unsure as the end of the degree apprenticeship loomed: "I'm kind of currently at the stage where I am deciding whether to stay… in engineering or whether to just change completely, going to like investment banking".

The three students who identified themselves with engineering had attended different schools in different parts of the country, came from different socioeconomic backgrounds and had different interests. However, their stories had one thing in common: all three had built trusted relationships with an adult whilst at school (a teacher in two cases, a scholarship mentor in the third) who had encouraged them to consider engineering as a profession before they had thought about it themselves. A first-year student said:

The (scholarship) mentor pushed me to apply, despite my response being that I was convinced maths was for me and that I was really unsure about engineering. He told me that strong mathematicians that loved problem solving were exactly what they were looking for and that getting the scholarship could open a wide array of opportunities for me. He convinced me that there was nothing to lose … I'm definitely indebted to him for doing so, I wouldn't have had that platform for industry connections and insights. Without that I think I would really have struggled to break down the misconceptions that I had of engineering.

For another student, it was a design and technology teacher: "My DT teacher… I spent an immense amount of time with him… and I started getting recognized within the classroom as the DT guy that everybody came to …". A year-four student commented: "My physics teacher, …, he kind of pushed me a little bit more towards engineering. And that's when I flipped from physics to mechanical engineering". Through those relationships, the students had been encouraged to push their boundaries and go beyond their academic curriculum. This also resulted in the three students having more or less formal teaching roles with their peers and, in one case, students at other colleges. These activities can be interpreted as a form of Peer Assisted Learning, defined as “the acquisition of knowledge and skill through active help and support among status equals” which has been found to enhance cooperative learning and communication skills as well as improving the student’s understanding of the subject under study (Gazula, McKenna, Cooper, & Paliadelis, 2017). By seeing their potential and encouraging them to do more for their peers, those adults had validated the students’ identity. By trusting them with additional responsibility, they had reinforced that identity. According to identity theory, the validation of role and group identities generate different results: whilst doing well in a class would generate feelings of self-efficacy, helping others to learn would also have a positive impact on the students’ self-esteem (Burke & Stets, 2009, p. 79). As the students had opportunities to do more of this, a positive feedback loop was established that led to greater trust and commitment.

One of the students in the first year often referred to herself and to her classmates as engineers: “sitting down in the kitchen with five other engineers I've never met before of my age and immediately you just have that ‘click’.” In contrast, despite being close to graduation, the fourth-year student who did not identify with engineering, never referred to herself as an engineer during the interview: “I know I can do engineering and I can be an engineer … it's just not necessarily where I see myself going 100%”.

In their responses to the TST, the three students with a strong engineering identity gave “I am an engineer” as one of their first four responses, whilst the student with low identification in engineering said: “I am an engineer by education”. Her reluctance to describe herself as an engineer would seem to confirm her lack of identification with engineering as a profession. She was also the only student to mention gender in her TST response (“I am a woman”). Research has found gender to be more salient for women in technical environments (Rees & Nicholson, 2000, p. 95) and it seems interesting that the female student who identified herself as an engineer did not feel the need to define herself as a woman, whilst the student with low identification with engineering did.

The research also sought to establish whether students with a strong engineering identity were more likely to report person identities that supported their role identity as an engineer (hypothesis three) (Burke & Stets, 2009, p. 124) and here the results were inconclusive; two of the three students with high identification with engineering gave more responses that aligned with the personal characteristics of engineers (analytical, hardworking, committed, dedicated) than the student with low engineering identification. However, some of the answers from the third student were hard to code (“I am saving for a house” or “I am motivated to finish my university degree”) and in that sense less helpful.

Conclusions

Degree apprenticeships expose students to academic learning in engineering disciplines and give them the opportunity to work in an engineering setting for the four years of the program, engaging students in multiple projects working with different engineering teams. It would be reasonable to expect that such exposure would have an impact on the engineering identity of degree apprentices. However, this initial study seems to indicate that it may not be the case and that students' engineering identity was already set by the time they started their degree apprenticeship. The students interviewed who arrived with a strong engineering identity, maintained it and the one who did not, failed to develop it. The findings of this initial study seem to confirm the following two hypotheses:

- Students with a strong engineering identity are more likely to have experienced trust in a formative relationship.
- Students with a stronger engineering identity are more likely to be committed to a future in engineering.

A fundamental premise of identity theory is that identity emerges in social interaction (Burke & Stets, 2009, p. 9) and this research would seem to confirm that. The results highlight the importance of relationships with teachers and mentors in fostering an engineering identity and would seem to confirm what identity theory proposes. It is interesting to note that the length of study does not seem to make a difference to the strength of the engineering identity; whilst first year undergraduates with a strong engineering identity happily describe themselves as engineers in the TST, a final year student chooses to describe herself as "an engineer by education". For the second hypothesis - whether students with a strong engineering identity are more likely to have personal identities that support their role identity as an engineer - the results are inconclusive and further research is needed.

Identity in general, and engineering identity in particular, is something that is not generally discussed in engineering education. It seems likely that engineering programmes would benefit from exploring and supporting the development of an engineering identity alongside the technical expertise associated with engineering qualifications. These findings would suggest that engineering educators need to build opportunities for students to explore and validate their engineering identities into their programs. For example, this might be achieved by developing closer relationships with students and by creating opportunities for students to verify their engineering identities through the integration of Peer Assisted Learning into the curriculum. Supportive personal relationships in an engineering setting develop trust, which in turn, develops students' commitment towards engineering as a profession.

The findings presented in this paper are from an initial study that focused on degree apprentices. This research is being expanded by including students enrolled on a conventional engineering degree at a university in England, and by conducting a larger number of interviews with both cohorts of university students and degree apprentices. The larger sample will enable further comparison between the early and later year students in order to extrapolate how engineering identity typically evolves during the four years of their education and will investigate in more depth students' future visions. In general, the methodology combining narrative enquiry and TST provided rich insights. The openness showed by the students who participated in this study and the depth of the insights they shared suggest that narrative enquiry is indeed a valuable methodology for the study of this important topic.

References

Armitage, L. Bourne, M. Di Simone, J. Jones, A. & Neave, S. (2020). Educational pathways into engineering. Engineering UK 2020.

Beam, T. K. Pierrakos, O. Constantz, J. Johri, A & Anderson R. (2009). Preliminary findings on freshmen engineering students' professional identity: implications for recruitment and retention. ASEE Annual Conference and Exposition. Austin. TX.

Beauchamp, C. & Thomas, L. (2009). Understanding teacher identity: an overview of issues in the literature and implications for teacher education. *Cambridge Journal of Education*. https://doi.org/10.1080/03057640902902252

Blumer, Herbert. (1963). Society as symbolic interaction. In *Human behavior and social processes*, edited by A. M. Rose. Boston. Houghton Mifflin.

Brickhouse, N. W., Lowery, P. & Schultz, K. (2000). What kind of a girl does science? The construction of school science identities. *Journal of Research in Science Teaching*. Vol.37 (5), p. 441-458. https://doi.org/10.1002/(SICI)1098-2736(200005)37:5<441::AID-TEA4>3.0.CO;2-3

Burke, P. J & Stets, J. E. (2009). *Identity theory*. New York: Oxford University Press.

Burke, P. J. & Stets, J. E. (1999). Trust and commitment through self-verification. *Social Psychology Quarterly*, 62. Pp. 347-66. doi.org/10.2307/2695833.

Burke, P. J. (2003). Relationships among multiple identities. In P.J. Burke, T. J. Owens, R.T. Serpe & P.A Thoits (Eds.), *Advances in Identity Theory and Research*. (pp. 195-214). New York: Kluwer Academic/Plenum. https://doi.org/10.1007/978-1-4419-9188-1_14

Cast, A. D & Burke, P. J. (2002). *A theory of self-esteem*. Social Forces 80, pp. 1041-68. https://doi.org/10.1353/sof.2002.0003

Cech, E. Rubineau, B., Silvey, S. & Seron, C. (2011). Professional role confidence and gendered persistence in engineering. *American Sociological Review*, 76(5), pp. 641-666. https://doi.org/10.1177/0003122411420815

Chaitin, J. (2004). My story, my life, my identity. *International Journal of Qualitative Methods*, pp. 3 – 4.

Costello, C. G. [published under Costello, C. Y.] (2005). *Professional identity crisis. Race, class, gender and success at professional schools*. Vanderbilt University Press. Nashville, Tennessee.

Cruess R. L., Cruess S. R., Boudreau J.D., Snell L. & Steinert, Y. (2014). Reframing medical education to support professional identity formation. *Academic Medicine*. 89 pp. 1446–1451. https://doi.org/10.1097/ACM.0000000000000427

Curasi, C.F. (2001). A critical exploration of face-to-face interviewing vs. computer-mediated interviewing. *International Journal of Market Research*. Vol 43 Quarter 4. https://journals.sagepub.com/doi/10.1177/147078530104300402

Department for Business, Innovation and Skills. (2015). English apprenticeships: Our 2020 vision. Great Britain. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/482754/BIS-15-604-english-apprenticeships-our-2020-vision.pdf

Eliot, M. & Turns, J. (2011). Constructing professional portfolios: sense-making and professional identity development for engineering undergraduates. *Journal of Engineering Education*, Vol. 100, No. 4, pp. 630-654. https://onlinelibrary.wiley.com/doi/10.1002/j.2168-9830.2011.tb00030.x

EngineeringUK, Key facts and figures. Highlights from the 2019 update to the Engineering UK report. https://www.engineeringuk.com/media/156198/key-facts-figures-2019-final-20190627.pdf

Gazula, S., McKenna, L., Cooper, S. & Paliadelis, P. (2017). A systematic review of reciprocal peer tutoring within tertiary health profession educational programs, *Health Professions Education*, Volume 3, Issue 2, pp 64-78. https://doi.org/10.1016/j.hpe.2016.12.001

Godwin, A. (2016). The Development of a measure of engineering identity. ASEE's 123rd Annual Conference and Exposition. New Orleans, LA, p. 1. https://doi.org/10.18260/p.26122

Gohier, C., Chevrier, J. & Anadon, M. (2007). Future teachers' identity: Between an idealistic vision and a realistic view. *McGill Journal of Education*, 42(1): 141–156.

Goodson, I. & Sikes, P. (2001). *Life history research in educational settings: Learning from lives*. Open University Press, Buckingham.

James. W. (1890). *Principles of psychology*. New York. Holt Rinehart and Winston.

Jarvis-Selinger S., Pratt, D.D. & Regehr, G. (2012). Competency is not enough: Integrating identity formation into the medical education discourse. *Academic Medicine*. 87. Pp. 1185–1190. https://doi.org/10.1097/ACM.0b013e3182604968

Williamson, J. M., Lounsbury, J. W. & Han, L. D. (2013). Key personality traits of engineers for innovation and technology development, *Journal of Engineering and Technology Management*, Volume 30, Issue 2, pp. 157-168.

Kuhn, M.H. & McPartland, T. S. (1954). An empirical investigation of self-attitudes. *American Sociological Review*, Vol 19, No 1, pp. 68-76. https://doi.org/10.2307/2088175

McAdams, D. P. (2007). The life story interview. Available from: https://cpb-us-e1.wpmucdn.com/sites.northwestern.edu/dist/4/3901/files/2020/11/The-Life-Story-Interview-II-2007.pdf

McGowan, V. C. & Bell, P. (2020). Engineering education as the development of critical sociotechnical literacy. *Science and Education*, Vol 29, pp. 981-1005. https://doi.org/10.1007/s11191-020-00151-5

McGrath, J. (2019). Analysis of shortage and surplus occupations based on national and Eurostat Labour Force Survey data. European Commission.

Mead, George H. (1934). *Mind, self, and society*. Chicago: University of Chicago Press.

Merriam, S. B & Tisdell, E.J. (2016). *Qualitative research. A guide to design and implementation*. 4th Edition. Jossey-Bass.

Monrouxe, L.V. (2009). Identity, identification and medical education: why should we care? *Medical Education*, Volume 44, Issue 1, pp. 40-49. https://doi.org/10.1111/j.1365-2923.2009.03440.x

Nicholl, B. (2009). The epistemological differences between a teacher and researcher: A personal journey illustrating second order action research. *Design and Technology Education: An International Journal*, v. 14, n. 3

Palinkas, L.A., Horwitz, S.M., Green, C.A., Wisdom, J.P., Duan, N. & Hoagwood, K. (2015). Purposeful sampling for qualitative data collection and analysis in mixed method implementation research. *Administration and Policy Mental Health Services Research*, 42, 533–544.

Patrick, A., Borrego, M. & Prybutok, A. (2018). Predicting persistence in engineering through an engineering identity scale. *International. Journal of Engineering Education*, 34(2(A)), Pp. 351-363.

Patton, M.Q. 1990. *Qualitative evaluation and research methods*. Second Edition. Thousand Oaks. Sage.

Pierrakos, O., Beam, T. K., Constantz, J., Johri, A. & Anderson R. 2009. On the development of a professional identity: Engineering persisters vs. engineering switchers. 39th ASEE/IEEE

Frontiers in Education Conference. San Antonio. Texas. Doi.org/10.1109/FIE.2009.5350571

Rees, A. & Nicholson, N. (2011) The twenty statements test in C. Cassell & G. Symon (Eds.), *Essential guide to qualitative methods in organizational research* (pp. 86 – 97). Sage Publications, London.

Stryker, S. ([1980] 2002) *Symbolic interactionism: A social structural version*. Caldwell, NJ. Blackburn Press.

Stryker, S. & Burke, P. J. (2000). The past, present, and future of an identity theory. *Social Psychology Quarterly* 63(4) pp. 284–297. Doi.org/10.2307/2695840

UCAS Website. (2021). Engineering and technology search. https://digital.ucas.com/coursedisplay/results/providers?searchTerm=engineering%20and%20technologyanddistanceFromPostcode=andstudyYear=2021andsort=MostRelevant (Accessed 11.07.2021)

Design and Technology Education: An International Journal

26.3

Social Connectedness and Online Design Learning Experience in the Indian Context

Christy Vivek Gogu, Indian Institute of Technology Delhi, India
Jyoti Kumar, Indian Institute of Technology Delhi, India

Abstract

The rise in online courses and virtual learning avenues in the last few decades, and more recently the Covid-19 pandemic has seen traditional design schools imparting learning seamlessly by transitioning to the virtual realm partially or completely. This study helps understand the perspective of students from various design schools across India regarding their learning experience in online courses, virtual classrooms and their perceived social connectedness with peers and educators. We report findings from a mixed-methods study, which combined both quantitative and qualitative data collection and analysis, wherein ninety-five students from five design schools across India responded anonymously to the online questionnaire survey. We assessed the factors that impacted perceived social connectedness of the students with their educators and peers in online classes. We also discuss some of the reasons for this perception, as articulated by the participants, and report a significant correlation found between felt connectedness and various factors in online learning, such as visibility of participants, level of interaction during class, interest in course and understanding of the subject. It was observed that while the target student group seemed adept in online interaction and exchange of information, their feedback on online learning revealed unique insights into aspects that affect overall experience of design education. In addition, we submit some of the features or elements of traditional face-to-face (F2F) classrooms that students miss the most in the current online setting and some of the measures taken by students and educators to stay connected and overcome the virtual gap in learning.

Keywords

Online design learning, social connectedness, design education, virtual learning, online class behaviour, behaviour design

Introduction

Social interactions are essential for human physical and psychological well-being. Social connectedness, which has been characterized as one of the main motivating principles behind social behaviour, is usually considered as a predictor of a successful life and it has been associated with many social and health-related benefits (Riedl, Köbler, Goswami, & Krcmar, 2013; Smith & Mackie, 2000). Van Bel, et al. arrived at the concept of Social Connectedness and defined it as ‘a short-term experience of belonging and relatedness, based on quantitative and qualitative social appraisals, and relationship salience’ (Bel, Smolders, Ijsselsteijn, & De Kort, 2009). The social connectedness construct has evolved out of the study of belongingness (Baumeister & Leary, 1995; Lee & Robbins, 1995). According to belongingness theory, people tend to develop and continue positive social relationships so as to experience a sense of belongingness. Social connectedness is also defined as a personal sense of belonging to a group, family, or community. For the purposes of their doctoral research, the author would like to define Social Connectedness as ‘the experience of belonging and relatedness between people’.

While the concepts, effects and benefits of social connectedness have been well researched in the social sciences and psychology scholarship, there is a lack of published research regarding social connectedness of students in traditional face to face college environments, which is instrumental in their learning and deep comprehension (Nortvig, Petersen, & Balle, 2018; Anastasiades, Filippousis, Karvunis, Siakas, Tomazinakis, Giza, Mastoraki, 2009). More so for design education which thrives on group work, collaboration, peer critique, building on each other’s ideas, etc. The design process itself is highly collaborative in nature, involving not just designers but specialists from multi-disciplinary backgrounds.

Empathy is a vital trait for a designer as understanding the user and their experience has a central place in user-centred design (Koskinen & Battarbee, 2003; Visser, Stappers, van der Lugt, & Sanders, 2005). ‘Empathic design’ (Koskinen et al., 2003) nudges designers to get closer to the lives and experiences of probable users, to increase the possibility of the product or service being designed to fulfil the user’s needs. Several tools and techniques have been suggested (Fulton Suri, 2003) to help support designers to ‘step into the user’s shoes’ so as to design products that meet the user’s needs. Research shows that social connectedness can enhance empathy (and vice versa) towards strangers and therefore can be learnt (Hutcherson, Seppala, & Gross, 2008). Therefore, a design learning environment that promotes perceived social connectedness can aid future designers to be trained in developing empathy that is essential for a more user-centred approach to designing.

With the increase in online education, it is imperative that design schools look for avenues to bring design education to their online recipients. Design practices have evolved over the years with the advancement in information technology and computer know-how. It is necessary to develop a new approach to teach and train students to adapt to the new design tools and methods (Chen & You, 2003). While online learning has been around for a few decades, design education is still not readily available online (Kumar, Kumar, Palvia, and Verma, 2019). Researchers have provided experimentally established guidelines for creating and maintaining social connectedness online which consist of strategies designed to facilitate status assessments, norm development, and role differentiation in computer-mediated communication channels that often lack the subtle social cues people use in face-to-face (F2F) interactions (Slagter van Tryon, 2007; Slagter van Tryon & Bishop, 2009). Laffey, Lin, and Lin (2006) claim education and various learning interactions, whether traditional F2F or virtual, to be social practices which is definitely true for a design education and practice. The extent to which students in online learning environments perceive themselves as being socially connected to their peers appears to be a key factor in predicting the success of online courses (Kreijns, Kirschner, Jochems, and van Buuren, 2004). While fruitful social interactions happen relatively effortlessly in F2F learning settings, creating, and maintaining these social connections in online learning environments require active support and, often, educator facilitation (Reisetter & Boris, 2004).

Design uses extensive studio-based exercises which makes it challenging for design educators to transition to technology-driven changes into an online teaching and learning environment (Bender, 2005; Fleischmann, 2018). With Studio-based learning being at its core, design courses usually have small class sizes and use project work and collaborative creative problem solving with many possible solutions (Blair, 2006). Research shows that online collaboration in design can be successfully done only if student participation is high and instructor feedback is instantaneous (Bender & Vredevoogd, 2006). Peer learning and group discussion form an integral part of the learning process (Park, 2011; Blythman, Orr & Blair, 2007).

Since 1993, numerous models of virtual design studios (VDS) have been introduced to design departments and schools all over the world, especially the architecture schools. This approach has gradually become part of IT supported design education. The organization and size of the VDS depends on the number of the projects, the number of participants, the types of digital media and tools applied, and duration of the project. The purposes and objectives of these VDS have slight differences, which can be divided into three categories: campus usage which provides support to design courses and design information communication (Budd, Vanka & Runton, 1999; Latch Craig & Zimring, 2000); design collaboration usage which provides the platform for school-to- school/country-to-country design collaboration in order to provide an opportunity for the students/teachers to work with other students or experts in other environment (Dave & Danahy, 2000; Russell, Stachelhaus, and Elger, 2003) and multidisciplinary collaboration which focuses on interdisciplinary design collaboration and provides a platform to integrate students with experts from different fields (Žavbi & Tavčar, 2005).

In design education, there has been some research done to inquire into the effectiveness and success of these courses but not sufficient to fully understand the impact on learning in online platforms (Turner, Rieger and Barrick, 2011). The characteristics of studio-based teaching in design have been identified as supporting interaction, active learning, as well as social engagement (Crowther, 2013), thereby involving high social connectedness amongst students and educators. Keeping all these in mind, blended learning is seen as a possibility where certain courses are taken online while others are studio based (Fleischmann, 2018).

This study aims at understanding student experiences that affect perceived social connectedness in online design courses and ultimately assess the impact, if any, of social connectedness on the students' course understanding, interest, and motivations.

Method

An inductive research approach was adopted to make observations and investigate thereby arriving at conclusions (Morse & Niehaus, 2009). Data was collected from ninety-five graduate and postgraduate level design students doing a combination of theory and practical courses in various branches of design, such as Product Design, Transportation Design and UX Design. The respondents were from five design schools in India, viz. Department of Design IIT Delhi, Pearl Academy Delhi, UPES School of Design Dehradun, United World Institute of Design Gandhinagar, and ISDI Mumbai. The online questionnaire survey, consisting of closed and open-ended questions to gain a wholesome understanding of student behaviour and responses with respect to online design courses, was considered to be the most suitable method to gather students' feedback for many reasons. Online surveys had the advantage of reaching a greater number of participants in a short amount of time, without any geographical constraints, especially during the pandemic related lockdowns. They were used to collect both quantitative and qualitative data simultaneously. They gave students the flexibility to participate as per their convenience of place and time. They also support the anonymity of respondents, allowing greater transparency and higher participation when well-designed, fast, and easy to complete (Gray & Malins, 2004).

For the quantitative data collection, a 5-point Likert scale was employed and students picked from a range of responses such as Always, Often, Sometimes, Occasionally, and Never (Robinson, Shaver, and Wrightsman, 1991), to help answer the 'what?', 'when?', 'how much?' or 'how often?' questions while the open ended questions allowed the respondents to give more in-depth, reflective responses in answering the 'why?' questions related to their online learning experiences (Fribourg & Rosenvinge, 2013). Ninety-five students from five design schools across India responded anonymously to the survey. These students had spent a part of their design course time in traditional F2F classes and had experienced the online classes for a few months prior to the survey.

To analyze the quantitative data obtained using the online surveys existing tools from the survey platform, Google forms and Google sheets were used. This data was also statistically analyzed to find any possible correlation between the critical variables and perceived social connectedness. The qualitative data obtained from the open-ended questions were coded and categorized into themes and subthemes, combining similar codes into subcategories and their frequency of occurrence or mentions was summed up to evaluate and assign significance. The findings and analysis are presented in the subsequent section, followed by a detailed discussion of some implications of the findings, future scope, and conclusions.

Results and Analysis

The results and analysis of the data collected during the study is shown through the following tables.

Online class hours and platforms used

Tables 1 and 2 show the no. of hours spent online and the online platforms used by the respondents for the design courses, respectively.

Table 1. Online design class hours

Online class hrs per week	<5	6-10	11-14	15-19	>20
No. of students	59	20	6	2	8

Table 2. Online platforms used for classes

Online class platform	Zoom	BB Collaborate	Google Meet	MS Teams	Others
No. of students	68	11	21	29	5

It may be noted that some students used more than one platform for various online classes. Hence, it was seen that a majority of students spent not more than an hour each day in online classes and the most popular (or preferred) platform was Zoom. It was essential to note that most students also used social media and other online platforms like WhatsApp, Miro, and

Mural to connect outside their formal online class time to collaborate with their classmates and work on projects or do assignments.

Online behaviour and class participation

The following figures in Table 3 indicate how often the students displayed certain behaviour online.

Table 3. Virtual behaviour in online classes

Virtual behaviour	Always (5)	Often (4)	Sometimes (3)	Rarely (2)	Never (1)	Mean	Var.
Video ON	2	10	28	34	21	2.36	1.02
Verbal interaction	9	29	23	28	6	3.08	1.26
Course interest	13	31	11	5	3	3.70	1.10
Chat messaging	4	21	39	25	6	2.9	0.91
Course understanding	9	44	29	9	4	3.46	0.89

The ‘virtual behaviour’ terms used in Table 3 are described further to gain a more comprehensive understanding of the questions asked in the survey. ‘Video ON’ corresponds to ‘how often the students kept their video camera turned ON during classes’; ‘Verbal interaction’ corresponds to ‘how often the students interacted with the educator or peers during the classes’; ‘Course interest’ corresponds to ‘how often the students were interested in the course they were attending’; ‘Chat messaging’ corresponds to ‘how often the students used the messaging or chat feature of the online platform during class’; while ‘Course understanding’ corresponds to ‘how often the students understood everything that was being taught in online classes’. The respondents marked the frequency on a scale of 1 to 5, where 1 stood for ‘never’ and 5 for ‘always’.

Similarly, student respondents marked the level of connectedness they experienced with their educator and peers on a 5-point Likert scale ranging from feeling ‘extremely connected’ to ‘not at all connected’. The results are as shown in Table 4.

Table 4. Experience of connectedness in online classes

Virtual experience	Extremely (5)	Very (4)	Neutral (3)	Not really (2)	Not at all (1)	Mean	Var.
Connectedness with educator	7	18	32	27	11	2.75	1.31
Connectedness with peers	3	12	29	35	16	2.47	1.04

It would be appropriate to note here that the students/respondents were not given any definition of the terms ‘social connectedness’ or ‘connectedness’, instead they were expected to use their own interpretation/perception of the term ‘connectedness’ according to their life and language experiences.

In the sections that follow, we see more analyses to better understand the various relationships between ‘Connectedness with educators/peers’ and other variables/ factors/ behaviours.

Correlation between variables and connectedness

Pearson’s correlation was applied to analyze the reciprocal impact of some of the prominent variables in online courses and student behaviour on the perceived social connectedness and the impact of this perceived connectedness on the course interest and understanding among students. Firstly, the three prominent variables in online courses were taken as ‘frequency of keeping video ON’, ‘verbal interaction in class’ and ‘using of chat/messaging feature’ as impacting the perceived social connectedness of students with their peers and educators. Secondly, the perceived social connectedness of students impacting their ‘interest in courses’ and ‘course understanding’. Significant correlations were found as shown in Table 5.

Table 5. Correlation between variables and connectedness

Correlation with connectedness (r.)	With educator	With peers
Video ON	-	0.251
Verbal interaction	0.291	-
Chat/messaging	-	-0.23
Course interest	0.419	0.255
Course understanding	0.27	-

A significant positive correlation is seen especially between ‘connectedness with the educator’ and ‘course interest’. This indicates that the students were more interested in the course when they felt higher levels of connectedness with the educator. Further, when students kept their videos ON more often, they felt more connected with their peers. Similarly, higher verbal interactions during class led to higher felt connectedness with the educator. Significant correlation was also seen between the level of connectedness felt with the educator and the understanding of the course taught. Contrary to expectation, a negative correlation was found between the frequency of chat/messaging options used in the class and the felt connectedness between peers. This will need further investigation to understand and establish as a phenomenon.

Self-evaluation of performance

The students were asked to evaluate themselves for their performance in online classes compared to that in in-person classes on a scale of 1 to 5, where 1 was ‘much worse than in-person’ and 5 was ‘much better than in-person’. The results are shown in the table below:

Table 6. Self-evaluation of performance

Self-evaluation of performance in online vs. in-person	Much worse than 1	Worse than 2	Same as 3	Better than 4	Much better than 5	Mean	Var.
Frequency	14	41	17	14	9	2.64	1.5

Table 7. Self-evaluation, connectedness, and course understanding

Correlation	Connectedness with educator	Course understanding
Self-evaluation	0.398	0.629

A significant correlation was also found between the students' self-evaluation of class performance and their felt connectedness with the educator and the course understanding. Further, the qualitative data obtained from the responses to the open-ended questions in the survey were tabulated based on the frequency of common themes that emerged from coding them. These tables help us gain some understanding of the 'why' behind the 'what', the reasons that made the students feel or not feel a sense of connectedness during the online classes.

Reasons for video ON/OFF behaviour

In the open ended (qualitative) questions, the respondents were asked to list some of the reasons why they kept their video camera ON/OFF during online classes. The reasons given(often more than one) are listed in tables 8 and 9 below, with the number of mentions of the same reason by multiple students.

Table 8. Reasons for video OFF behaviour

Reasons for keeping video OFF	No. of mentions	Sample responses
Technical Poor internet, no webcam	41	'Internet Connectivity/Bandwidth issues'
Self-image Not dressed appropriately, not looking good, Feel conscious	18	'Reluctance to show myself', 'I usually feel conscious when I keep my video on', 'It is difficult to maintain proper professional attire throughout the day at home'
Peer behaviour No one keeps it ON	5	'Nobody else was keeping their video on', 'I don't want to be the only one visible'

Home situation Workspace setup not suitable, lighting, visual disturbance	35	'My workplace doesn't have "Workplace" look', 'other family members in the house', 'don't have great lighting at my place', 'to avoid background interruptions due to home environment'
Comfort Still in bed, multitasking, not interested/needed	16	'If it's morning class I'm usually still in bed when I attend', 'Ability to multitask (have lunch, sketch, etc.)'

Table 9. Reasons for video ON behaviour

Reasons for keeping video ON	No. of mentions	Sample responses
Technical Good internet/bandwidth	7	'Good internet speed', 'strong network'
Self-image Well-Dressed, feeling confident	5	'Felt Confident to show myself that day'
Peer behaviour Helps in interaction, other students' behaviour, able to express/converse better	12	'To express something properly. And to have livelier conversations'
Concern for Educator Someone must keep the video ON, requested by Prof	6	'Will be difficult for the faculty to teach looking at a screen where everyone has turned off their camera', 'As requested by professor'

Reasons for perceived connectedness

After rating the perceived level of connectedness with their educators, the students answered open-ended questions to explain what made them feel connected with the educators and the responses (often multiple reasons) are listed below in Table 10.

Table 10. Reasons for connectedness with educators/peers in online classes

Reasons	No. of mentions	Sample responses
Interactions Discussions/teamwork, chat options, breakout room, express oneself, interactive presentations, fun interactions, social media	46	'Having similar doubts, sharing work', 'A lot of students live in different cities and family environments which impact thoughts and ideas. It was interesting to see and hear the variety of ideas that

		came from other students while at home', 'We used to meet informally too'
Presence Being able to see others, video on, knowing my classmates are there, hearing their voices, togetherness	18	'If their videos were on and verbal communication ensued', 'The feeling of nostalgia that we mutually shared'
Instructor input Voice/video/feedback, course content, guidance, effort taken, personal attention, questioning	22	'Getting timely feedback from mentor', 'The course curriculum requirements', 'Faculty kept their video ON... tried to continuously connect with students, engage them in various activities including short assignments', 'Sharing real world stories, examples', 'hearing familiar voices', 'presentations'
None/not sure	17	'It's really hard.', 'Required lots of effort.', 'Nothing ever really helped'

The most common factor that helped students feel a sense of connectedness in online classes was having interactions with the educators or students and doing collaborative work as part of class. The chat option in some of the platforms also aided in connectedness. More than a sixth of the respondents felt there was nothing that helped them feel connected in online classes.

Reasons for perceived lack of connectedness

The students also gave reasons as to why they felt a lack of connectedness or disconnectedness with their educator and peers. The responses are listed in Table 11.

Table 11. Reasons for lack of connectedness in online classes

Reasons	No. of mentions	Sample responses
Lack of Interaction No discussions, monologues, session too long, limited online time, fun is missing	57	'When the session went on for a long duration and got monotonous', 'Some ideas are better communicated through in person interactions and ideation sketches are more difficult', 'no physical interaction', 'everyone is very formal'
Physical/Visual absence Can't see others/video OFF, not there physically	31	'Videos are OFF', 'only instructor was talking'

Technical issues Internet connection, audio issues	23	'Poor internet connection...', 'The confusion when everyone talked at the same time', 'video not visible, when someone shares screen'

In attempting to find the reasons for the respondents' lack of felt connectedness in online classes, it was found that most of them felt that the lack of interaction of students in the classroom or college campus was a key reason followed by physical and/or visual absence. Attending classes from home also added domestic distractions and made it difficult to be motivated and focused enough to work well. Students also missed out on peer-learning and building on each other's ideas.

Advantages of online classes

The main advantage of the online courses, according to the study, was the convenience and flexibility it afforded the students to connect from the comfort of their homes or anywhere else, eliminating time and effort taken to commute. Ease of access to online resources and features like breakout groups and recording options were found beneficial, especially for theoretical courses. Students often used social media or online platforms like WhatsApp, Miro and Mural to connect outside of class time to connect, collaborate and work on group projects.

Elements missing in online classes

In attempting to understand aspects of F2F classes that the design students missed the most during online classes, the students responded descriptively, as summarized in Table 12, with a few sample responses.

Table 12. Elements missing in online classes

Elements	No. of mentions	Sample responses
Interactions Discussions/teamwork, conversations/sharing ideas, debates/critique/feedback/ clarification, accountability, more focus, easier/faster learning	51	'Having similar doubts, sharing work' 'The instant feedback while doing a work, project or assignment to correct the mistakes and easily move on', 'A very small but crucial element missing for me was the little discussions we would have with the other students about the same topic while it was being taught 😋. It added to the understanding of the subject matter.'
Physical presence Being with/seeing each other, body language/expression, movement, hands-on work	28	'Meeting friends, having fun in class, proper discussions, looking at faces' 'The fact that we could see each other physically and have a lot of fun as well as learn in a much more effective way compared to online classes.'

Ambience Classroom/studio, college/school, learning/work environment	19	'Learned more in two months of offline classes then six months of online classes', 'The atmosphere is different. It is after all a place not dedicated to learning, when studying from home or from other places doesn't have the same effect.' 'The workspace and people which made the aura of a good working environment' 'The atmosphere is different. It is after all a place not dedicated to learning, when studying from home or from other places doesn't have the same effect', 'The workspace and people which made the aura of a good working environment'
Fun aspect Laughter/fun activities, energy, attachment	13	'The energy of the class sessions, with a lot of back-and-forth interaction', 'Human interaction that is organic and the laughter that came with studying'
Everything	9	'Every single moment'

Affirming their previous responses, almost 80 percent of the respondents said they missed the animated discussions and organic interactions the most in the online setting. They explained how these discussions helped them get a better grasp of topics being taught in class or clear any doubts they had with their educators. These interactions also helped them learn from their peers.

Changes suggested in online classes

Finally, the students were asked that if given a change, what would they like to change about the online classes. Their responses are recorded in Table 13 below.

Table 13. Changes suggested for online classes

Suggested changes	No. of mentions	Sample responses
More interaction short lectures, more interaction, group assignments/activities, time for chit-chat during class, online avenues to meet with faculty members, mandatory camera ON time in each class, 2-way communication	11	'Proper one-to-one conversations by the instructors as everyone's not able to concentrate properly in online classes', 'classes with active communication (both-way)', 'n the beginning of the lecture, compulsory 10 mins of free time discussion with faculty and all the students, with their cameras on, so that it would be easy for everyone to get comfortable at first and attentive throughout the lecture', 'There should be different channels where we can meet all

		professors separately based on their available time slots, similar to the way we do in faculty offices.'
More like in-person Holograms, VR,	4	'I would definitely make the class appear more like an in-person class (Holograms may be)', '3D or VR lecture so we can at least have vibe to feel like in the actual classes'
Recorded lectures Can be heard anytime, multiple times, while working on hands-on learning, more presentations	4	'Emphasis on shorter durations and availability of recorded lectures', 'More presentations, less class time'
Hybrid classes Theory online, practical in-person	2	'I would prefer 50-50% setup where half the classes would be offline (including lab sessions)'
Small class size Efficient communication, less isolation, better understanding, better connected	4	'Short sessions with few students at once, say half a class - 10-15 students, might bridge the gaps between the instructor and the student', 'It might also not create a sense of isolation that is there when it comes to online classes'
No online classes	3	'Nothing. I would rather avoid online classes'

Discussions

Highlighted through the results and analysis is the importance of being able to see each other and interact with people in physical or virtual space. Although the internet can be a great space to meet and connect with people, it has its limitations due to the visual and physical gap that can be closed only by physical presence and interaction, especially in online design education. And yet, we see many design educators and students successfully exchanging knowledge and ideas to impart and receive design education. We can get a more holistic understanding of the experiences design educational setups by also considering the perceived social connectedness of design educators and its effect on pedagogy, which has been studied as precursor to this study and reported earlier (Gogu & Kumar, 2021) wherein educators talk about the challenges they face, and measures taken by them to connect with students better in online education. However, this study focused on gathering insights on how the students were responding to online design education and taking initiative to bridge the digital divide. It reinforced the fact that it was more natural and intuitive to create bonds and work collaboratively when meeting peers in person rather than online. While it is possible to form collaborations online, it took more effort and initiative on the part of students and instructors alike.

The significant correlation seen between the students' perceived connectedness with educators and their interest in the course, verbal interaction in class and understanding of the course, emphasizes the fact that students need to feel a sense of connectedness with their educators in order to take more interest in the course and participate more in the class, leading to a better understanding of the course matter. The correlation found between connectedness with peers, visible faces, and verbal interaction in class indicates that being able to physically see each other and talk to and interact with each other plays a key role in feeling a sense of connectedness between peers.

It needs to be further investigated whether an increase in interest in a course could presumably result in better learning and performance of a student in the course. Though the study shows that higher perceived connectedness of students with educators was also related to higher understanding of the course and self-evaluation of students.

The students in this study also mentioned that while in in-person classes, giving/ receiving feedback was intuitive and fast, it was also easier to clarify doubts and make quick changes in the design process, something they missed tremendously in online classes. This suggests that further investigation is required to study and compare the current LMS platforms to identify specific improvements that can be done to make them more intuitive when it comes to receiving feedback or clarifying doubts.

Even though there is (and most likely, always will be) a clear preference for in person or F2F learning experience, we saw that students found ways to stay connected outside of online class hours, discovering and adapting to new platforms to collaborate for team projects by finding avenues to replicate in-person interactions and exchange of ideas. Interestingly, the self-evaluation done by students seems to show that higher perceived connectedness with educators resulted in greater understanding of the subject and thereby higher self-evaluation of performance in the online mode. Therefore, there is a need for design educators to constantly encourage visibility, verbal interaction, and participation in online settings. Further, they could incorporate collaborative tools as add-ons to the online platforms they are already using to encourage in-class participation and interaction, thereby heightening the learning experience for both the students and themselves.

Conclusions

This article reports that, as expected, design students preferred traditional F2F learning environments rather than the online option. They felt the in-person environment gave them a more holistic learning that happens due to focused learning and higher interest generated just by the experience of creative and curious minds learning and interacting together. Since these students were suddenly moved to online mode of learning due to the pandemic-imposed lockdown, they didn't have much choice. Perhaps once things normalize, they would see that having an option to do certain courses (or parts of a course) online, while others in person might also have its benefits as suggested in literature on blended learning.

The study reiterates that the primary drawback of online classes in design education was immediate critique during ideation, the lack of perceived social connectedness resulting in lack of organic group interactions and collaborative work. Whereas the primary advantage of an online learning mode was found to be the flexibility it grants in terms of attending from any location and time. Some students also mentioned that thanks to online mode they could continue their education without wasting precious weeks, which later had turned to months and years.

Considering the feedback from the survey participants, it may be concluded that:

1. Significant correlation was seen between the students' perceived connectedness with educators and their interest in the course, verbal interaction in class and understanding of the course. Correlation was also found between connectedness with peers, visible faces, and verbal interaction in class. This could mean that being able to see their instructor and peers, greater interaction in class made the students feel more connected with their instructors and peers and increased their interest in their course.
2. The increase in interest in their course could presumably result in better learning and performance of the students, which needs to be further investigated. The study shows the perceived connectedness with educators also related to the understanding of the course and self-evaluation of students.
3. The current online platforms need improvement to make them more intuitive when it comes to receiving feedback or clarifying doubts as also found in another research (Pratap, Dahiya & Kumar, 2021).
4. The study confirmed earlier findings that students found it difficult to do collaborative work and group projects online, which is an integral part in traditional F2F classrooms (Fleischmann, 2018).
5. Lack of proper Internet and power connectivity are practical problems still faced by students in many parts of developing India. Also, studio/workshop facilities and classroom environment are missing in online setups.

Most of these students had experienced online classes only for a few months at the onset of lockdowns imposed due to the Covid pandemic. Therefore, further research is warranted to be carried out over a longer duration to understand and compare the deeper impact of online courses on the perceived social connectedness and ultimately design learning. Technology focused research could help identify features that can help make the online learning experience a more rewarding one. Conducting neurophysiological studies on student experiences is another possibility for future studies.

References

Anastasiades, P.S., Filippousis, G., Karvunis, L, Siakas, S., Tomazinakis, A., Giza, P., Mastoraki, H. (2009.) Interactive Videoconferencing for collaborative learning at a distance in the school of 21st century: A case study in elementary schools in Greece, *Computers & Education,* Volume *54*, Issue 2, Pages 321-339, ISSN 0360-1315, https://doi.org/10.1016/j.compedu.2009.08.016.

Baumeister, R. F., & Leary, M. R. (1995). The need to belong: Desire for interpersonal attachments and fundamental motivation. *Psychological Bulletin, 117,* 497–529.

Bel, D., Smolders, K. & Ijsselsteijn, W. & De Kort, Y. (2009). *Social connectedness: Concept and measurement.* 67-74. 10.3233/978-1-60750-034-6-67.

Bender, D. M. (2005). Developing a collaborative multidisciplinary online design course. *The Journal of Educators Online, 2*(2), 1-12. doi:10.9743/jeo.2005.2.5

Bender, D. M. and Vredevoogd J. D. (2006). Using Online Education Technologies to Support Studio Instruction. *Educational Technology & Society, 9* (4), 114-122.5.

Blair B. (2006). ‘At the end of a huge crit in the summer, it was “crap” – I’d worked really hard but all she said was “fine” and I was gutted.’. *Art, Design & Communication in Higher Education, 5*(2), 83-95. doi:10.1386/adch.5.2.83_1.

Blythman, M., Orr, S., Blair, B., (2007). Critiquing the Crit: University of the Arts London. Retrieved from https://www.academia.edu/586074/Critiquing_the_Crit

Budd, J., Vanka, S. & Runton, A. (1999). The ID-Online Asynchronous Learning Network: a 'Virtual Studio' for Interdisciplinary Design Collaboration, *Digital Creativity*, *10*:4, 205-214, DOI: 10.1076/digc.10.4.205.3233

Chen, W. and You, M. (2003). A framework for the development of online design learning environment, *The proceeding of the 6th Asian Design International Conference (CD ROM), Integration of Knowledge*, Kansei, and Industrial Power, October 41-17, 2003, Tsukuba International Congress Center, Japan, No. 584.

Crowther P. (2013). Understanding the signature pedagogy of the design studio and the opportunities for its tech. enhancement. *Journal of Learning Design, 6*(3), 18-28.

Dave, B. & Danahy, J. (2000). Virtual study abroad and exchange studio, *Automation in Construction, Volume 9*, Issue 1, 2000, Pages 57-71, ISSN 0926-5805, https://doi.org/10.1016/S0926-5805(99)00048-5.

Fleischmann, K. (2018). Online design education: Searching for a middle ground. *Arts and Humanities in Higher Education,* 1-22. doi:10.1177/1474022218758231

Fribourg O. and Rosenvinge J. H. (2013). A comparison of open-ended and closed questions in the prediction of mental health. *Quality and Quantity, 47* (3):1397-1411.

Fulton Suri, J., (2003). The experience evolution: developments in design practice. *The Design Journal*, *6* (2), 39–48.

Gogu C. V. and Kumar J. (2021) Social Connectedness in Online versus Face-to-Face Design Education: A comparative study in India. In *Design for Tomorrow-Volume 2*, Smart Innovation, Systems and Technologies 222, https://doi.org/10.1007/978-981-16-0119-4_33.

Gray C. and Malins J. (2004) *Visualizing Research: A Guide to the Research Process in Art and Design.* New York, USA: Burlington Ashgate.

Hutcherson, C. A., Seppala, E. M., & Gross, J. J. (2008). Loving-kindness meditation increases social connectedness. *Emotion, 8*(5), 720–724. https://doi.org/10.1037/ a0013237

Koskinen, I. and Battarbee, K. (2003). Introduction to user experience and empathic design. *In*: I. Koskinen, K. Battarbee, and T. Mattelmäki, eds. *Empathic design, user experience in product design.* Helsinki: IT Press, 37–50.

Kreijns K., Kirschner P. A., Jochems W., and van Buuren H. (2004). Determining sociability, social space, and social presence in (a)synchronous collaborative groups. *Cyber Psychology & Behaviour, 7*, 155–172. doi:10.1089/109493104323024429.

Kumar P., Kumar A., Palvia S., and Verma S. (2019). Online business edu research: Sys. analysis and a conceptual model. *The Intl Journal of Mgmt Edu, 17*, 26-35.

Laffey J., Lin G. Y., and Lin Y. (2006). Assessing social ability in online learning environments. *Journal of Interactive Learning Research*, *17*(2), 163 – 177.

Latch Craig, D. & Zimring, C. (2000). Supporting collaborative design groups as design communities, *Design Studies, Volume 21*, Issue 2, 2000, Pages 187-204, ISSN 0142-694X, https://doi.org/10.1016/S0142-694X(99)00041-1.

Lee, R. M., & Robbins, S. B. (1995). Measuring belongingness: The Social Connectedness and the Social Assurance scales. *Journal of Counseling Psychology, 42*(2), 232–241.

Morse J. M. and Niehaus L. (2009) *Mixed Method Design: Principles and Procedures*. Walnut Creek, CA: Left Coast.

Nortvig, A. M., Petersen, A. K., and Balle, S. H. (2018). A Literature Review of the Factors Influencing E Learning and Blended Learning in Relation to Learning Outcome, Student Satisfaction and Engagement. *The Electronic Journal of e-Learning, 16*(1), pp. 46-55

Park, J. Y. (2011). Design education online: Learning delivery and evaluation. *International Journal of Art & Design Education, 30*(2), 176-187. doi:10.1111/j.14768070.2011.01689.x

Pratap S., Dahiya A., Kumar J. (2021) From Studios to Laptops: Challenges in Imparting Design Education Virtually. In: Zaphiris P., Ioannou A. (eds) *Learning and Collaboration Technologies: New Challenges and Learning Experiences.* HCII 2021. Lecture Notes in *Computer Science, vol 12784*. Springer, Cham. https://doi.org/10.1007/978-3-030-77889-7_35

Reisetter M. and Boris G. (2004). Student perceptions of effective elements in online learning. *Quarterly Review of Distance Education, 5,* 277–291. Retrieved from http://www.aect.org/intranet/publications/qrde/subguides.html.

Riedl C., Köbler F., Goswami S., and Krcmar H. (2013). Tweeting to feel connected: A model for social connectedness in online social networks. *International Journal of Human-Computer Interaction*, 29, 670–687.

Robinson J. P., Shaver P. R., and Wrightsman L. S. (Eds.). (1991). *Measures of social psychological attitudes, Vol. 1. Measures of personality and social psychological attitudes.* Academic Press.

Russell, P., Stachelhaus, T. and Elger, D. (2003). CSNCW: Computer Supported Non-Cooperative Work Barriers to Successful Virtual Design Studios. *Digital Design* [21th eCAADe Conference Proceedings / ISBN 0-9541183-1-6] Graz (Austria) 17-20 September 2003, pp. 59-66.

Slagter van Tryon P. J. (2007). E-mmediacy strategies for online learning: An instructor's guide and instrument for the design and evaluation of social connectedness in web-based courses. Lehigh University.

Slagter van Tryon P. J. and Bishop M. J., (2009). Theoretical Foundations for Enhancing Social Connectedness in Online Learning Environments. *Distance Education 30*(3):291-315. DOI: 10.1080/01587910903236312.

Smith E. and Mackie D. (2000). *Social psychology (2nd ed.),* Psychology Press, New York, NY

Turner R. E., Rieger M., and Barrick R. K. (2011). Student Evaluation Scores for Courses Delivered by *Interactive Videoconferencing NACTA Journal, Vol. 55*, No. 1, pp. 16-20.

Visser, F.S., Stappers, P. J., van der Lugt, R. & Sanders, E. B-N. (2005) Context mapping: experiences from practice, *CoDesign, 1*:2, 119-149, DOI: 10.1080/15710880500135987

Žavbi, R., and Tavčar, J. (2005). Preparing undergraduate students for work in virtual product development teams, *Computers & Education, Vol. 44*, pp. 357-376.

Design and Technology Education: An International Journal

26.3

The connectivist design studio

Miroslava Petrova, Universidad de Monterrey, Mexico

Abstract
The design studio is the core element in the design curriculum where students gain key knowledge and skills. Typically implementing a project-based approach, it is characterised by learning by doing, collaborative learning and a prominent studio culture. The traditional notion is that the social domain of the studio has a counterpart in the physical environment. However, with the pervasion of information and communication technologies, the design studio was inevitably transferred to the digital realm. When the traditional face-to-face studio had to be transferred to an online modality enforced by covid-19 pandemics, re-conceptualization of the structure was required in order to ensure the quality of the teaching and students' satisfaction. Based on the premise that the contents should not be simply adapted to an online version but an entirely new learning experience should be created, the redesign of the class was inspired by the principles of connectivism (Siemens, 2005). Connectivism as an alternative learning theory recognizes the societal shifts and the impact of technology on the learning processes. This new framework for understanding learning, states that knowledge is derived externally of the individual through a process of connecting nodes and patterns recognition.

The paper explores the potential of connectivism applied in two online design studios at the University of Monterrey, Mexico. It describes the structure of the course and the results obtained in the online learning environment. The outcomes are verified in a survey on the perceptions of the students about their satisfaction and the effectiveness of their knowledge acquisition.

Keywords:
Connectivism, design studio, online design studio, online learning environment, learning experience, knowledge creation

Introduction
The digital realm of the 21st century profoundly changed the design process and inevitably influenced teaching and learning. Among the priorities of design education is to prepare students for the challenges of the profession in the new reality. To provide the necessary knowledge and skills to deal with the environmental complexity while ensuring positive learning experience requires constant evolution and implementation of new methods and practices in the learning process. Recognizing that learning today is done through networks and that "[k]nowledge is "not a "thing," or a system, but an ephemeral, active process of relating" (Stacey, 2003), connectivism is advanced as a relevant theory to aid pedagogy and its successful adaptation to the digital context. The aim of the paper is to explore the potential of connectivism applied in two online design studios of the interior design undergraduate program at the University of Monterrey, Mexico. It describes the structure of the course and the results obtained in the online learning environment. The outcomes are verified in a survey on the perceptions of the students in regard to their satisfaction and the effectiveness of their knowledge acquisition.

Background

From Beaux-Arts and Bauhaus to the virtual design studio

The design studio is the core element in the design curriculum where students gain key knowledge and explore their creative skills (Salama, 1995). Originating in the Ecole des Beaux-Arts in Paris (1819–1968) the architectural atelier is where students learn to design. It was run by a patron, an experienced master architect, who would guide students how to improve and develop further their designs, and transmit his theories of architecture while discussing their drawings. Just as important was the co-learning which occurred between the students. They exchanged ideas and shared their knowledge in preparation for the annual competition Grand Prix de Rome which was an essential part of the architectural education. The new and old members of the atelier constantly helped each other – the old ones criticizing the work of the new ones, who on their part assisted the seniors with the execution of their drawings. The relationships between the patron and the students were friendly, combined with respect and reverence (Chafee, 1977).

The other pedagogical concept which impacted the structure of design education worldwide was introduced in Bauhaus (1919–1933). After successful accomplishment of the preliminary course where students were introduced to the fundamental elements of design, they enrolled in a specialized workshop by their choice (furniture, pottery, weaving, stained glass, sculpture, metal, wall-painting, theatre). The founder of Bauhaus Walter Gropius described the workshops as "the most important part of our preparation for collective work." These "laboratories for working out practical new designs for present-day articles and improving models for mass-production" were run by two masters – a craftsman and an artist, ensuring that the student would acquire solid technical skills to deal with the material as well as artistic skills to master the aesthetic form of the product (Gropius, 1965). Though becoming a stage of numerous conflicts of the ambitions, beliefs and convictions of the leading masters and their apprentices, the educational experiment was very successful in creating a democratic community. It recognized the equality of the various crafts and gave everyone the opportunity to be liberated and grow anew as a creator of the new age through unifying technology and art (Forgacs, 1995).

Certainly, the implementation of the structure and pedagogy of these antecedents in the design curricula has undergone many changes and adaptations through the years to respond to the current needs of the society and its value system. However, their main elements – learning by doing and collaborative learning are retained to this day. Typically implementing a project-based approach, the studio is where students "express and explore ideas, generate and evaluate alternatives, and ultimately make decisions and take action" (Gross & Do, 1997).

Through the critical dialogue that is established and the provided feedback, students test the validity of their ideas, and constantly try to improve them. In this constant process of experimentation and revision, learning occurs through reflection of the relation between the action and the resulting outcomes. This "reflection-in-action" as Schön defines it (Schön, 1987), is particularly important for knowledge acquisition. Students learn how to articulate the experience, how to control the process and eventually to become independent in taking decisions. Another aspect of these activities is that they occur in certain social context and hence they are not bound to the individual but involve collaboration (Bruce &Bloch, 2012). In the studio environment, students interact with the instructor and their peers and not only learn how to communicate both verbally and visually their own concepts but also listen to the viewpoints of the others thus gaining new understanding of the problems discussed.

To generalize the important role of the studio in architectural education, Ledewitz summarizes that it provides teaching of new skills (visualization and representation among them), new language of designing where the verbal and non-verbal dimensions are interlinked (Schön , 1983), and architectural thinking, characterized by a specific for the profession approach to problems (Ledewitz, 1985).

However, central characteristic of the studio is not pedagogy but the interactions that take place and which form the exemplary atmosphere or the studio culture. Wang describes it as "a vital complex of material representation, social collaboration, creativity, emotionality and a tolerance for uncertainty – if not outright confusion – balanced with a faith that meaningful designs eventually will emerge" (Wang, 2010).

The traditional notion is that the social and cultural domain of the studio has a counterpart in the physical environment where students spend long hours, create their own community of practice, and identify with it as individuals and as a group (Spruce, 2007). However, with the pervasion of information and communication technologies both in the design practice and the educational process, the design studio was inevitably transferred to the digital realm. Driven by the growing complexity of the design problems and the higher demand for collaboration between all participants involved in the design process, in the early 1990s the virtual design studio emerged (Radojevic, 2007). The new studio typology offers a computer-mediated collaboration, often between geographically distributed and multicultural teams that is space and time independent (Maher, Simoff & Cicognani, 2012). Though considerably different from the physical space, the virtual studio has the same function as a shared learning and practice space where students interact, develop and present their projects. Furthermore, an important fact is that a sense of place can be fostered (Maher & Simoff, 1999) and hence the identity and the community typical for the face-to-face studios can be successfully retained. A major benefit of the experience in a virtual design studio is that students are exposed to a simulation of the real working environment where expertise in digital media and collaboration in multidisciplinary teams are prerequisites. In the virtual studio students master the new digital tools and develop competences which help in bridging the gap between academia and the professional practice.

Design teaching after covid-19 – in search of a new learning theory

Design education has undergone significant development in the past decades to respond to the technological and social changes and to adequately prepare students for their future career. Digital technology has been extensively embraced by the educational system to facilitate the learning process and to improve the quality and effectiveness of the teaching. Enabled by Web 2.0 online learning brought a radical change in the educational context with its accessibility, independence of time and space and the ability to promote varied interactions with the content, the instructor and the other learners. However, the giant leap to online learning was not a natural result of its advantages but was externally imposed by the covid-19 global pandemic when it proved to be the only possible way for the educational process to continue. University educators were faced with the fact that in the changed setting learning occurs in a different way. They had to rapidly adapt and discover the new opportunities for teaching and learning afforded by the online environment.

The content of the studio classes I teach also had to be re-evaluated and a plan how to present and transform the information in a relevant way was required. To ensure the quality of teaching and to respond to the needs and expectations of the students, the contents could not be simply transferred to the online version of the class. Instead, the teaching approach had to be fundamentally rethought to propose entirely new experience for the students. Guided by the principle summarized by Laurillard that "[k]nowledge technologies shape what is learned by changing how it is learned," (Laurillard, 2012) the aim was to provide a systematic organization of the content and to plan the class interaction by combining the best pedagogical practices of the traditional face-to-face class with the emerging possibilities afforded by the virtual environment.

To understand the effects of the technological context on education and to support the planning of the online design studio a relevant theory is needed. Determinant factor to be considered is the changing nature of the design process. The commonly accepted notion of its structure consists of two situations – an identified problem that needs to be resolved and a solution which fulfils a certain goal. The transformation from one state to the other, or the causal link between the two situations, is the act of design (Findeli, 2001). From the perspective of systems and complexity theories, Findeli suggests that instead of a problem and a solution, two end states of the system should be considered – its present state and its desired future state which is never a specific solution but a transitory state in a dynamic process. In this new structure, the designer and the user are also considered parts of the system that undergo changes during the transformation process. The awareness of the systematic nature of design requires attention to be paid to the invisible relations that exist between the actors within the system and not on the artifact as an outcome of the design project. This new understanding might be the radical change needed in design education and the design studio in particular which are in a state of crisis (Wang, 2010).

The future designers need to be trained how to deal with the increasing complexity of both the design problems they have to resolve and the design process which often requires a multidisciplinary approach to the design project. To support the acquisitions of skills and prepare them for the challenges of the profession within the context of the fourth industrial revolution, learning should not be focused on the accumulation of knowledge but on the ability to seek for the most up-to-date information, to filter it and to apply it when making decisions. Again, the importance of the relations within the highly abundant and rapidly changing information network and the ability to explore them is prioritized. Hence, the application of systems and complexity theory in learning can provide the demanded framework and foster the required change in education.

In his seminal work "Connectivism: A Learning Theory for the Digital Age" Siemens questioned the viability of behaviorism, cognitivism and constructivism as theories adequately addressing the learning processes in the digital age (Siemens, 2005). He advanced connectivism as an alternative learning theory recognizing the societal shifts and the inevitable impact of technology on learning processes. He reconsidered the relationships between knowledge and the learners in the current social environment and proposed a novel understanding that knowledge is derived externally of the individual through a process of connecting nodes and patterns recognition. According to connectivism, knowledge is a network phenomenon, composed of networked entities and their connections (Downes, 2010). A major tenet is that knowledge is considered as a function of elements distributed across a system; it is decentralized and may exist outside of a person, which implies that "know where" becomes more important than to "know what" and to "know how." Learning is considered as a continual network-forming process in which knowledge is created through the construction of new connections between fields, ideas and concepts. It evolves from knowledge consumption to a knowledge creation process (Siemens, 2006).

Though the status of connectivism of a theory has been criticized (Verhagen, 2006; Kop & Hill, 2008) its conceptualization of learning accurately reflects the context defined by the online learning environment and the changed student demographics. Thus, its application as a pedagogical approach in the design studio is considered pertinent.

Connectivist learning in the online design studio: the case of the University of Monterrey (UDEM)

Research method and data collection

To study the effect of the implementation of connectivism in an online studio class the case study as a strategic qualitative research method was adopted. The aim is to provide holistic understanding of the connectivist studio through investigating the causal link between what was planned and what occurred as a result, giving priority to students' point of view. The perceptions of the students and their own estimation about the achieved outcomes of the class were examined with several surveys which were carried out before, during and at the end of the semester. The questionnaires were designed to collect both quantitative and qualitative data. To measure students' satisfaction a 5-point Likert scale was used where they could select levels of the statements ranging from very high, high, neutral, low and very low or strongly agree, agree, neutral, disagree, strongly disagree. To provide additional insight on the quality of the applied pedagogy and to discuss the positive and negative aspects of the online studio in comparison to traditional studios open questions were included in the survey where students could express more freely their opinion. In this way the effectiveness of the teaching strategy was verified and valuable recommendations were received on what to change and how to improve the online learning environment. Data were collected from two studios delivered during two consecutive semesters in 2020 and 2021 with the participation of 30 students in total, with 15 interior design students enrolled in each of them.

Context

The studio takes a central place in the four-year undergraduate program of Interior Design at the University of Monterrey, Mexico. From the very beginning of the course of study, students are exposed to studio work which each subsequent semester features a changing focus of the subject and increasing complexity. Successful completion of the previous studio is required for the students to enrol in the next studio and to continue their studies. The first class transformed from a traditional studio into a fully online mode in the autumn semester in 2020 was "Studio Integral." This is the last and most advanced studio which allows students to apply progressive theoretical approaches in the development of a comprehensive large-scale project. It was followed by the "Institutional Spaces" studio for sixth semester students in the spring semester in 2021. At this level of their education, students are already experienced in developing concepts and using a variety of representational techniques so the main objectives of both studios are to deal with advanced interior design problems. The focus is put on experimentation with various strategies to create innovative and inspiring spaces, satisfying the physiological, psychological, social, cultural and environmental requirements. Special attention is paid to the sociological and technological shifts which are transforming present-day interiors. Furthermore, students explore the experiential aspects of the space and learn how to create a sense of place and memorable spatial experiences.

The major questions considered in the planning process of both online studios were:

- How to minimize the negative effects of transferring the highly practical and dependent on human interaction design studio into the online modality?
- How to plan for effective communication and collaboration in the online learning environment?
- How to engage students and how to encourage a more autonomous and self-directed learning?
- How to ensure meaningful knowledge acquisition in the online learning environment?
- How to support new types of interaction so that the authentic culture and practice of the design studio is preserved?

The first aspect taken into account was the profile of the students. The impact of technology on millennial students' behaviour, beliefs, attitudes and educational requirements has long been recognized and researched with the intention to implement learning activities which are meaningful and conform to their learning needs (Petrova, 2014). However, in 2020 a new digital native generation is in the classroom and though sharing some characteristics with their predecessors, they certainly have their differences. To understand the characteristics and the learning preferences of the cohort it is imperative to support the students through their learning journey and to maximize their engagement in the educational process. Generation Z students are described as observers with a preference for visual and video-based content. They identify themselves as intrapersonal learners who are used to learning in their own setting before sharing their knowledge with others. They focus on acquiring the skills needed for their future career and expect to immediately apply them in real life. Moreover, they feel highly motivated when they are engaged with their passions and when they are involved in social change initiatives (Seemiller & Grace, 2018).

A main goal of the design of the teaching strategy was not to focus on the content but to align the learning outcomes with the proposed activities so that each student is enabled to master competencies while comprehending the value they add for his professional development.

The expected learning outcomes were formulated as follows:

- Ability to implement systematic design approach to solving problems
- Skills to develop and structure a design narrative as a prerequisite for a successful design solution
- Ability to translate conceptual ideas into tangible forms and spaces
- Analytical and critical thinking skills for generalization, evaluation and selection of structures, constructions and materials

- Mindset to apply integrative design approach for sustainable solutions
- Presentation skills and ability to defend concepts and ideas with well-grounded arguments
- Interdisciplinary and heuristic thinking

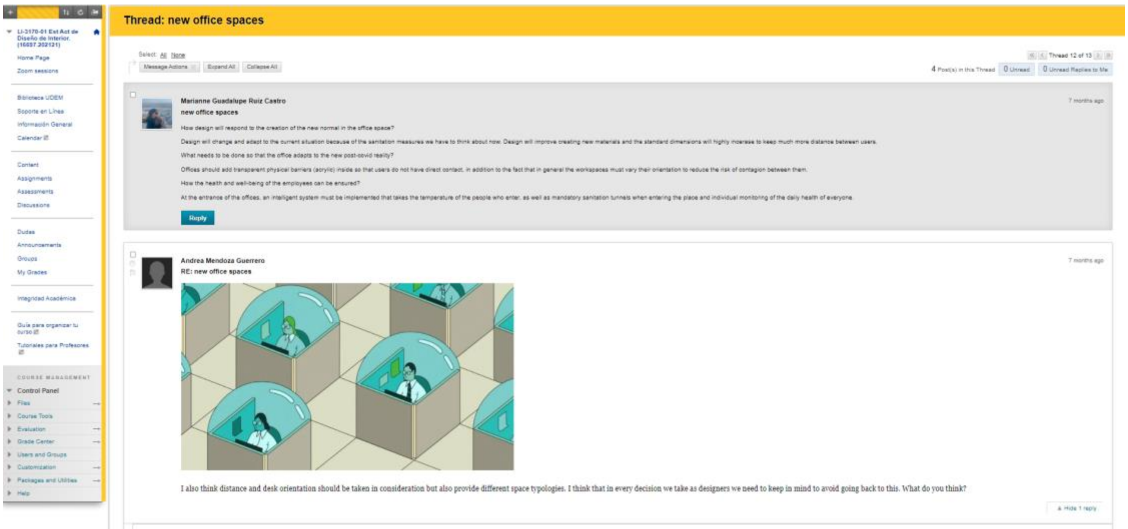
Contrary to the departmental requirement that the course content should be well-defined and preliminary structured, a flexible program was proposed which could easily adapt to changes and self-organize according to the needs of the students.

Following connectivist principles a variety of perspectives and opportunities for students to connect and to establish dialogue were offered. I relied on the interactions which would be naturally formed and the spontaneous emergence of learning through these interactions.

Peer connection is one of the options for learning to occur in the online environment. For example, the first activity in the Institutional spaces studio to define the building typology was intended to encourage students to work collaboratively and to create understanding of the topic together as a group. The use of the online whiteboard platform miro.com allowed the teacher to monitor the work of the students, to pose additional questions for students to consider and to suggest hints if doubts occurred (Figure 1).

Figure 1. Mapping the institutional space – collaborative peer activity to discover the typology of institutional spaces using miro.com as an online platform

The didactic content was not hierarchically structured but instead was split into small segments that could be easily re-arranged and personalized according to the prior knowledge and individual interest of the students. The theoretical lectures, additional readings and videos supporting the concepts which were to be explored in the design process were uploaded on Blackboard – the learning management system adopted by the university, for students to review at their own pace. At the same time, students were encouraged to research these concepts further, to collect reference materials and through reflexion and self-critique to move from observation to interpretation. A major premise in this teaching strategy is that the students are responsible for their own learning. However, in general, they are accustomed to receiving precise instructions and prefer to be guided in the development of the assignments. To prevent them from getting lost in the massively abundant information and to create a feeling of security, the synchronous sessions in the beginning of the semester were devoted to creating an atmosphere of trust and confidence. The provided nodes of theoretical content served as guidelines for the initial building of a personal knowledge base while the online discussion forums resolved doubts and supported students in the process of self-directed autonomous learning (Figure 2).



a)

b)

Figure 2. a) Discussion on Blackboard about the design strategies that can be applied to adapt the office space to the new post-covid reality, b) Student presentation with design ideas about the implementation of the strategies

The acquisition of skills to recognize which information is valuable and authentic is crucial for the formation of a sound knowledge base of the subject. Today students are exposed to excessive amount of information and books or textbooks are no longer the major source of knowledge they use. At the same time, a lack of attention given to the issue of authority when evaluating websites is observed (Rowlands, 2008). To learn how to evaluate critically the validity and relevance of the data they encounter on the internet, students were required to use the electronic services of the library in order to verify the information they encounter on the internet. The identified theoretical concepts were summarized in various mind-maps which were shared between the students for peer and group critique (Figure 3).

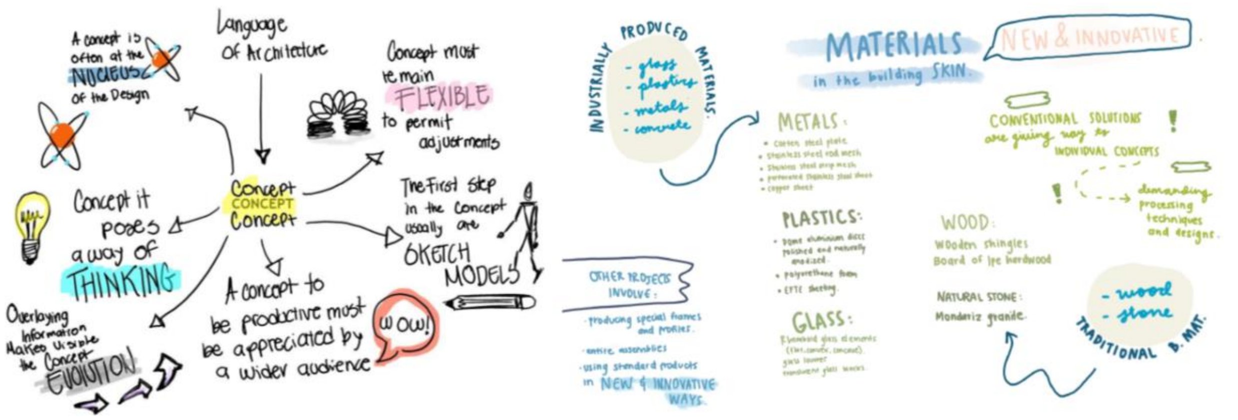


Figure 3. Mind-maps representing student's understanding of the theoretical concepts

When understanding of the basic concepts has been developed, students could move on to the next level where through interactions with a new content they could form new connections. The formation of new and unexpected connections between existing ideas and the most up-to-date concepts results in new forms of knowledge and this is the essence of the creative process. Not only analytical and critical thinking but also interaction and discussion are decisive for students to be able to "see" these new connections (Figure 4). The feedback provided by peers and the instructor during the synchronous sessions aided in distinguishing the valuable inputs.

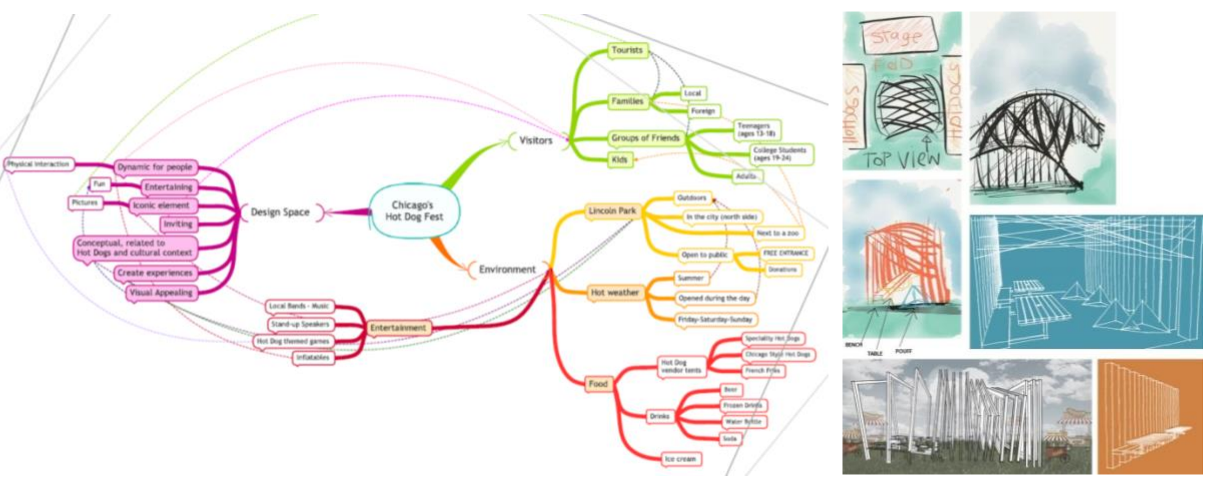


Figure 4. Mind-map exploring the existing relationships between the major aspects considered in a pavilion design and the resulting concept sketches

Another important aspect of connectivism is that students are expected to contribute to the knowledge network by sharing insights and disseminating their own knowledge. Engagement and active participation of each student is expected. In this knowledge co-creation process the main role of the teacher is to curate and sustain the learning environment, to monitor and control its effective functioning, to motivate the self-directed learning and to create opportunities for knowledge sharing. Such an opportunity was provided with the implementation of the Collaborative Online International Learning program (COIL). This virtual mobility experience offered the possibility to interact with students from another country – Universidad de San Francisco de Quito (USFQ) in Ecuador in 2020 and the San Pedro College in the Philippines in 2021. Thus, the online classroom was transformed into a third space (Bhabha, 2004) where "we bring together and negotiate cultures, identities, values, perspectives, relationships, contexts, or ideas from two spaces in an attempt to move into a new space, albeit imaginatively, and create a hybrid space that results from a new creative understanding and juxtaposition of aspects of both spaces" (Ikpeze, 2015). The construction of this hybrid space gave a new contextual meaning to the explored ideas and created new possibilities for creative thinking (Figure 5). Furthermore, by encouraging cross-national dialogue students were able to expand their own networks in a culturally diversified environment.

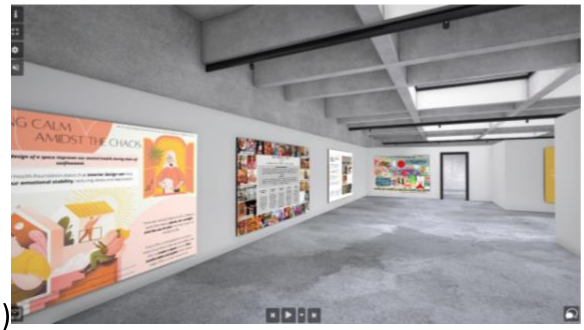
a)  b) 

Figure 5. a) "Creative fragments" virtual exhibition (collaboration between UDEM and USFQ, 2020), b) Online exhibition featuring the results of the COIL research posters using the VR exhibition space on artsteps.com (collaboration between UDEM and San Pedro College, 2021)

Evaluation of the results

Some of the findings of the surveys carried out three times during each semester are presented in the infographic on Figure 6. One of the most satisfying results was that all 30 students enrolled in the two studios found the class to be very well planned and would not change anything in the future. Also, all students replied positively to the question "Did you find the learning in the studio meaningful?" Another survey question addressed the perception of the level at which the class prepares students for their professional practice. 60% indicated a "very high" level, and the other 40% evaluated the level as "high." Likewise, all students considered that their personal achievements in the class as "very high" which was also confirmed with my direct observations.

However, in the answers to the question whether the online studio can replace the face-to-face classes prevail the opinion that traditional classes are indispensable as 83% preferred them. Among the reasons were pointed out that communication is better in person than talking to a camera, because working in front of the computer for long hours has been very tiring, and distractions occur more often at home. Still, students found a lot of advantages of the online studio. A respondent commented, “I liked the class very much, I think that the teacher understands that the online class is harder for us but she makes it very interesting and useful, also not that difficult, and always supports us.” Another student shared, “Yes, I think the proposed type of learning made us more responsible. We, as individuals, are responsible of our own learning. Learning goes way further than connecting to the class, we have to be present and have the best attitude in order to be able to learn”. Another opinion which summarizes the advantages of the teaching strategy is, “This class has helped me improve my level of organization and my design process.”

An indicator of the success of the proposed teaching strategy is the changed attitude of the students towards the responsibility for their own learning. While at the beginning of the semester 87% responded that they prefer to receive precise instructions how to develop the assignments and only 30% were willing to search additional references and readings not assigned by the teacher, at the end of the semester 28 of the students defined themselves as self-directed learners and two were uncertain. The feeling of belonging to the community was also confirmed by 93% of the students.

Conclusions

One of the findings which require some changes to be implemented in the future is that 77% of the students think that the overload of the online class is higher than the traditional face-to-face class and all of them felt very tired at the end of the semester.

Particularly interesting is the comment from one of the students who shared, “Thank you for caring about our experience with online classes. This is the first time a professor takes the time to ask important questions about this type of learning.” This is found as a big shortcoming because educators should always be aware of the effectiveness of their classes as there is a direct relation between the selected method of teaching and the learning outcomes. And this is especially important to be identified in the online environment which most likely was completely new for the majority of the teachers in the beginning of the pandemic.

At the end of the semester, students were asked to reflect on their own learning and to assess whether they have acquired the skills initially listed as learning outcomes of the studio. The affirmative answers by all students make me consider the implementation of connectivism very successful.

References

Bhabha, H. K. (2004). *The Location of Culture*. Routledge, London

Bruce, B. C., Bloch N. (2012). Learning by Doing. In Seel N. M. [Eds] *Encyclopedia of the Sciences of Learning*. Springer, Boston, MA

Chafee, R. (1977). The Teaching of Architecture at the Ecole des Beaux-Arts, In Drexler, A. [Ed.] *The Architecture of the Ecole des Beaux-Arts*, MIT Press, Cambridge, MA

Downes, S. (2010). Learning networks and connective knowledge. In *Collective intelligence and E-Learning 2.0: Implications of web-based communities and networking*, pp. 1-26

Findeli, A. (2001). Rethinking Design Education for the 21st Century: Theoretical, Methodological, and Ethical Discussion. *Design Issues* Vol. 17 (1), pp.5-17

Forgacs, E. (1995). *The Bauhaus Idea and Bauhaus Politics*. Central European University Press https://archive.org/details/bauhausideabauha0000forg/page/28/mode/2up?q=community

Gropius, W. (1965). *The New Architecture and the Bauhaus*. MIT Press, Cambridge, MA

Gross, M., Do, E. (1997). The Design Studio Approach: Learning Design in Architecture Education. In J. Kolodner & M. Guzdial [Eds] *Design Education Workshop*. EduTech/NSF, College of Computing, Georgia Institute of Technology, September 8–9

Ikpeze, C. H. (2015). *Teaching Across Cultures : Building Pedagogical Relationships in Diverse Contexts*. Sense Publishers. The Netherlands, Rotterdam

Kop, R., Hill, A. (2008). Connectivism: Learning theory of the future or vestige of the past? *International Review of Research in Open and Distance Learning* , Vol.9 (3)

Laurillard, D. (2012). *Teaching as design science. Building Pedagogical Patterns for Learning and Technology*. Routledge

Ledewitz, S. (1985). Models of Design in Studio Teaching. *Journal of Architectural Education,* Vol. *38*(2), pp. 2-8, 1985

Maher, M., Simoff, S. (1999). Variations on the virtual design studio. In *Proceedings of Fourth International Workshop on CSCW in Design*, pp. 159–165

Maher, M., Simoff, S., Cicognani, A. (2012). *Understanding Virtual Design Studios*. Springer

Petrova, M. (2014). Educating Designers from Generation Y – Challenges and Alternatives. In *Proceedings of the International Conference on Engineering and Product Design Education*. Twente, The Netherlands

Radojevic, M. (2007). Codification of Site Related Knowledge in Virtual Design Studios. In *Design Studio Pedagogy: Horizons for the Future* [Eds] A. Salama & N. Wilkinson, ARTI-ARCH

Rowlands, I. et al. (2008). *Information behaviour of the researcher of the future*. https://edu.au.dk/fileadmin/www.dpu.dk/viden/temaeraaa/informationskompetence/subsites_informationskompetence_20100223144624_information-behaviour.pdf

Salama, A. (1995). *New Trends in Architectural Education: Designing the Design Studio*. ARTI-ARCH

Schön, D. (1987). *Educating the Reflective Practitioner*. Jossey-Bass, San Francisco, CA

Schön, D. (1983). *The Reflective Practitioner: How Professionals Think in Action*. Temple Smith, London

Seemiller, C., Grace, M. (2018). *Generation Z: A Century in the Making*. Routledge

Siemens, G. (2005). Connectivism: A learning theory for a digital age. *International Journal of Instructional Technology and Distance Learning, 2*(1), pp. 3–10

Siemens, G. (2006). *Knowing Knowledge*. Lulu.com

Spruce, J. (2007). Examining the Role of the Studio Environment within Design Education. In *Proceedings of the International Conference on Engineering and Product Design Education*. Newcastle-upon-Tyne, UK

Stacey, R. (2003). *Complex Responsive Processes in Organizations: Learning and Knowledge creation*. Routledge

Verhagen, P. (2006). *Connectivism: A new learning theory?*

Wang, T. (2010). A New Paradigm for Design Studio Education. *Journal of Art and Design Education*, 29.2, pp.173-183, NSEAD/Blackwell Publishing Ltd.