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Less *Generation Z*, more *Jumanji*

Lyndon Buck, Aston University, UK
Kay Stables, Goldsmiths, University of London, UK

Welcome to the second issue of the journal for 2021. As we enter what will hopefully be the final chapter of the current pandemic (although we seem to recall that we said exactly the same thing back in the last DATE editorial four months ago), this issue provides opportunities for sharing recent research alongside some speculation about how things might change, what lessons have been learned, and what future research may focus on. The issue includes five research articles, a reflection piece and a book review. The research articles fall broadly into two categories with the first two reporting on research into the implementation on digital technologies in design and technology classroom activities whilst the final three articles are more focused on pedagogy, with the final two articles focused on undergraduate industrial and product design learning and teaching approaches.

The last year has shown us what living through a global pandemic is really like, and surprise, surprise it's not much like what Hollywood predicted. Gun toting virus infected monkeys (*Dawn of the Planet of the Apes*, 2014) and a zombie dodging Brad Pitt (*World War Z,* 2013) are nowhere to be seen, although London did look reminiscent of a scene straight from Danny Boyle's 2002 film *28 Days Later* for most of 2020. What has been most people's reality, especially for those of us working in education, has been a year spent learning and applying new learning and teaching technologies, fighting for limited resources, and dealing with the inevitable and very real human issues, both our own and those of others around us. In this issue's reflection piece Deborah Winn compares the difficulties faced by teachers of practical subjects in the last year or so as like being in the rope bridge scene in the 2019 film *Jumanji: The Next Level*, having to move forward at all costs while being chased by psychotic monkeys. We are sure that we can all empathise with her. So while Hollywood may have got it wrong in their many depictions of post pandemic scenarios, we can perhaps all agree that there are some movie scenes that seem to fit the bill quite well, hence the title of this editorial (it does rhyme if you say it in an American accent, which we are sure you have all have done in your heads). Hopefully this issue will provide us with some food for thought and allow us to reflect on our own educational practices as we consider how best to approach the next stage of this saga.

The first research article focuses on the use of augmented reality (AR) in practical classroom situations. In *Using augmented reality (AR) in vocational education programs to teach occupational health and safety (OHS)*, Renk Hülagü and Önder Erkarslan from Izmir Institute of Technology, Turkey present research from a study into the teaching of occupational health and safety (OHS) in Turkey within secondary schools and universities, with a view to designing a new system of teaching OHS using AR to raise awareness of risk, make students more cautious and appreciative of the task at hand, and therefore hopefully reduce accidents. They discuss

the need for students to experience risk in order to develop safe working methods in workshop activities and an appreciation of precautions and safety measures. The case study experiments

were conducted with few changes to work practices or existing machines and workshop set ups, and the systems used received positive feedback from students, with a noticeable decrease in potentially dangerous mistakes and fewer students in both control groups forgetting their PPE or using it incorrectly. The authors discuss the potential development of a low-cost AR OHS training system using a projector mounted over a lathe which may be an interesting project to develop within the Design Technology community, especially when student's hands on machine time and therefore their exposure to risk may be increasingly limited due to a number of external factors.

In *ePortfolios in craft education at the primary level: Teachers' experiences on ICT integration,* Virva Törmälä from Tampere University, Finland discusses the effects of the 2016 introduction of the Finnish National Core Curriculum (NCC) and its encouragement of pupils documenting their craft working practices. This study looks at the challenges of implementing an electronic portfolio (ePortfolio), and ICT more broadly, for craft education in a Finnish primary school context. The NCC encourages the use of digital technology to document pupil's working processes and digital documentation more widely. Using multimodal content on an iPad it is evident that the initiative is a useful and timely introduction to digital documentation and a useful way to map pupil progress in their craft activities, but there were several problems with the ICT implementation, the tools themselves and the differing level of digital literacy among the participants. While it is encouraging to see the Finnish NCC pushing the introduction and development of digital technologies it is evident that there remain barriers to their successful use at primary level. The use of ePortfolios in craft education, especially at primary level, could still prove to be a very useful and interesting development and this is a promising area of research for ICT and Design Technology educators.

In *The Reciprocal Nature of Pedagogical and Technical Knowledge and Skill Development between Experts and Novices,* David Gill from Memorial University of Newfoundland, Canada discusses what impact an expert teacher's pedagogical and technical knowledge and skill may have on their students, in this case technology education student teachers. By looking at the tutor student relationship in traditional wood boat building workshops in Newfoundland and Labrador, Canada, David traces the link between expert and novice in knowledge transfer and skill development and the importance of fostering and mentoring activities in the learner teacher relationship. By considering what it means to be an expert and how novices tend to use reductionist or heuristic techniques to simplify their experiences, we can begin to consider how students move from novice to mastery of a subject. The importance of having or gaining a real practical understanding and experience of the techniques of the task in hand is a prominent theme, along with how the technical perceptions of the instructor and the student can vary. Although the case study is based on a very specific craft context, that of traditional boat building, the student teachers reported that they were constantly thinking about how this experience could be applied to their own classroom situations in the future, not least in how it helps to structure and compartmentalise tasks. The importance of relationship building and of reflection in the task is stressed, as is the need to consider practical hands-on activities that

make students consider the formulation of teaching and learning. By considering new and different learning environments and activities for student teachers perhaps we can help them develop greater technical knowledge as well how the reciprocal relationship between expert and novice can shape their pedagogical practice.

In *Embedding Design Sprint into Industrial Design Education*, Ozan Soyupak from Osmaniye Korkut Ata University, Turkey explores the use of design sprints as a mechanism for students to explore their design and creative thinking through rapid innovation. The article discusses the shift in product and industrial design from physical to beyond physical, and how design sprints can be used in a wide variety of situations where innovation is a key required outcome. By focusing on design thinking as a human-centred problem-solving approach, Ozan traces the development of design thinking methodologies and frameworks, and design sprints in particular, and how these can be applied in an educational setting. While design sprints can be used across many areas of the curriculum, including in ICT and computer science, by comparing the concepts of design thinking and design sprints we can begin to understand the traditional relationship between industrial design educational practices and those of the profession. A three and a half day intensive design sprint workshop was held for undergraduate Industrial Design students where students determined the subject of the design sprint. Design sprints allow students to explore a design study using a well-defined structure with an experienced facilitator, and although the results appear similar to those of more traditional studio-based practices, the students reported a less hierarchical and more democratic approach to the task, with a more collective feel to the work and a feeling of independence through the activity. They also appreciated the close link between and within other actors in the design activity and, as such, the students began to more fully appreciate the multidisciplinary nature of the process.

The final research article in this issue continues the focus on higher education industrial and product design pedagogy and curriculum. *Phenomenological Approach to Product Design Pedagogy: A Study on Students' Experiences in Interdisciplinary and Intercultural Settings,* Fausto Orsi Medola, Luciana Ramos Baleotti, Aline Darc Piculo Santos, Ana Lya Moya Ferrari, and Amanda Coelho Figliolia from São Paulo State University (UNESP), Brazil and Nenad Pavel from Oslo Metropolitan University, Norway discuss the use and importance of design critique in design studio education, and how it can cause misunderstandings in interdisciplinary and intercultural teams. A four week study looked at undergraduate students of product design and occupational therapy in Norway and Brazil working on a project that targeted the demands of people with disabilities. The authors note the perceived importance of experience in product design education – the emphasis on students being able to do it (practice design) rather than theorise about it, and that designers tend to be generalists with a wide knowledge base to allow for creative inspiration. While critiques have traditionally been used to facilitate critical thinking in the design studio, the authors suggest that a move towards more immersive design learning spaces are better suited to develop real world skills and behaviours. The focus on design for people with disabilities, and collaboration with rehabilitation professionals, allows students to focus on user centred design and empathic practices within an inclusive design framework. By looking at the student expectations and their evaluation of experience and engagement it became clear that the use of a co-design process methodology, in collaboration with users and other members from other professions, led the students to be more creative and innovative. By focusing on the affordances and constraints of the interdisciplinary design process, rather than the critical reflection of constructed knowledge of the traditional critique,

it is hoped that the learning environments become richer and a greater focus on learner immersion in the task at hand may be the most beneficial learning outcome of this approach.

In addition to the research articles, this issue also includes a reflection by Deborah Winn of Neale-Wade Academy, UK and Daniela Schillaci-Rowland of Presdales School, UK and a review of a recently released book from the Center of Excellence for Technology Education (CETE).

In *Reflections on teaching Design and Technology in a pandemic*, Deborah Winn and Daniela Schillaci-Rowland reflect on the challenges faced by design and technology educators in 2020/21 in two different school settings. In what is our first reflection piece by practising Design Technology teachers in the DATE journal, Deborah and Daniela remind us of the rapid production of 650,000 items of PPE by Design and Technology departments across England while the constant change of rules and advice left them feeling like characters in Jumanji. While the authors report on the many challenges of the rapid shift to digital teaching and learning, not least the production of appropriate resources and the associated increase in workload from learning new technologies, it is evident that some students and teachers responded very positively to the shift, and a renewed focus on creativity and the learning opportunities offered to students may be very positive outcomes for the future development of the subject.

Finally, we have a review from Jonas Hallström from Linköping University, Sweden of the recently published book by the Center of Excellence for Technology Education (CETE) *The Impact of Technology Education: International Insights* edited by Marc J. de Vries, Stefan Fletcher, Stefan Kruse, Peter Labudde, Martin Lang, Ingelore Mammes, Charles Max, Dieter Münk, Bill Nicholl, Johannes Strobel, and Mark Winterbottom.

We hope that you enjoy this issue.

Reflections on teaching Design and Technology in a pandemic

Deborah Winn, Neale-Wade Academy, UK
Daniela Schillaci-Rowland, Presdales School, UK

Introduction
This article is a reflection on teaching by two teachers, Deborah Winn and Daniela Schillaci-Rowland, in different schools during the global pandemic of 2020/21. Deborah's school is a rural school of approximately 1500 11- 18 year old students. The school has a reasonably high percentage of disadvantaged students and students with vocational rather than academic aspirations. Daniela's school is a smaller all girls school with approximately 1000 11-18 year old more academically minded students on roll. There are many similarities but also some differences to the experiences, which is likely to be the situation worldwide. It seems that few schools were able to respond in the same way due to the number of students isolating, differences in time the schools were closed, parent buy in, access to computers and resources, etc.

The difficulties encountered by teachers, particularly in practical subjects, cannot be underestimated. When Deborah reflected on what it was like to teach in this time an image immediately came to mind of the rope bridge scene in Jumanji - the next level, where the characters are running across rickety bridges in the air that keep moving while being chased by psychotic monkeys. At first teachers weren't sure what they needed to achieve or how long they needed to continue for but they knew they needed to get there quickly. Rules and advice were constantly changing and multiple people, from examination boards, school hierarchy and parents, all wanted our intentions documented in detail. On deeper reflection however, students and teachers adapted quickly to a new way of working and whilst it was a stressful challenge, there were a number of positives that have come out of teaching in this period.

Not least was the rather monumental achievement made when Design Technology departments across England rose up like a small army in response to a need for personal protection equipment (PPE) by key workers in the first 'lock down'. This focused mainly on full face visors and mask clips. Collectively teachers produced and distributed over 650,000 pieces of PPE very rapidly. It is difficult to know how many were made as not all schools said how many they had produced, but the figures were impressive.

Other positives caused a reflection on current practice which required more creative approach es to teaching. Some of these are likely to, or at least should, continue beyond the pandemic.

Unprecedented times!
Whatever the experiences, it is likely that the moment teachers found out that everything had changed will stay with them forever. Daniela reminisces that growing up, she was fascinated by the stories people would tell when recalling events in history, and how they felt at the time and the specific things they could remember. In future generations, Covid will be spoken about in schools and stories passed down generations in the same way.

Daniela remembers that at 5.11pm, Wednesday 18th March 2020, she was standing next to the computers in her classroom, talking to her Design and Technology examination group students about finalising their design portfolios. A student announced “Breaking News, exams have been cancelled!”. A brief moment of silence followed. Then a student asked “Miss, what shall we do?”. What else would a Design and Technology teacher advise two days before the final examination submission deadline? “Carry on, we need to get the portfolios completed!”. For the next two days, school leavers’ assemblies were organised, lockers were emptied, and goodbyes were said, with us not really knowing whether we would be back in school in a few weeks, months or longer. During April 2020 it became apparent that we would not be going back into the classroom before June 2020 at the earliest, but that we should try to ensure students had a good offering of Design and Technology, and to try and keep things as close to ‘normal’ as possible. By the beginning of June, some students were able to be back in school, which meant that the introduction of the design portfolio was in-line with previous examination year groups at least.

For Deborah, the school had already shut the previous week and she recalls, “we had been called to a whole school meeting at the end of the day and fully expected to be told to be prepared for school closures. We dismissed our students and headed for the meeting where we were told we were shut as of this moment. Students would not be returning for at least two weeks but expect more”. In reality the students did not return to the school for face to face teaching for nearly six months. There were no goodbyes for the final year students and work and belongings were left where they sat at the end of that day like in a ghost town. It was a shock to say the least.

Digital learning & teaching

The ‘what next’ happened quickly, the pandemic jettisoned even the most reluctant teachers and students into fully exploiting the opportunities for using digital technologies for teaching and learning but also for meetings, parent’s evenings and training. For in-service training this reduced the cost, the need to travel and the need to be out of school all day. Materials could be easily shared, facial expressions were still able to be seen, unlike in a phone call, and as many videoed meetings it was possible to revisit and clarify points made. Even when life returns to normal it is likely more training and some meetings will be available in this way as people have become used to this way of working, making it more easily accessible to a greater number of people. For teaching the experiences of both students and staff are mixed however, for Design and Technology teachers the ‘bread and butter’, so to speak, is built around a subject where they barely sit down during the day, the world in which we embarked was not one that could easily be adapted to.

During March to July 2020 some schools were able to move lessons online fairly seamlessly. Daniela reports that without lack of computers at home being a barrier the transition, though not without its complications, had been reasonably successful. Schemes of Learning were adapted slightly for 11-14 year olds, to ensure that testing and evaluation of the termly projects were completed. For the examination years luckily they were beginning new topics that were more theory based, preparing them for the start of their design projects, so this seemed a little easier to prepare. Ironically, a year earlier, Daniela’s school had begun the process of creating and using an online learning platform, mainly to be used for homework. Google Classroom,

seemed to give a headstart on some other schools with regards to virtual learning, which meant that work was set, marked and fed back on weekly. Not seeing students or being able to discuss how to improve their work was difficult, but manageable. Deborah's school experienced far greater difficulties. Not all students had a computer, parents working from home or multiple siblings needing the computer meant that some struggled to access the work. It was not a level playing field for individual students or schools.

The Lockdown in January 2021 took many by surprise, however teachers had seen the dwindling numbers of students in school, with some schools reporting whole year groups having to isolate. This period of online learning felt different to the first. With the barriers largely removed many of the schools moved to complete online learning. The experiences of the schools again differed. Daniela reported that student engagement did not appear to be as good as the previous lockdown, and many schools were in limbo with mock examinations - whether to continue with them online or to cancel them. However for Deborah teaching, for all intents and purposes, remained as normal as possible in her school, which was a contrast to the previous lockdown. Surprisingly a number of students produced better work than they had when at school. The reasons for this are unclear, possibly due to lack of distractions - students were not able to go out and had no one to chat to so could be otherwise bored. Possibly it gave students some structure and purpose to their day that could otherwise be lacking. Some students obviously still struggled, home life and the resulting stresses from the pandemic were varied as were student responses but largely the move to online teaching was successful for a larger number of students. Both Daniela and Deborah agree this was however no substitute for face to face learning.

Some of the difficulties to online teaching were creating appropriate resources. Unlike in a classroom it wasn't possible to walk around and check understanding and progress therefore direction needed to be more explicit. Teachers also needed to be mindful that some students were accessing the lessons on their phones so may not see detail clearly or may not be able to flip screens as easily or complete computer based tasks. Differentiation was also complicated by needing to keep the direction on screen to a minimum. Strategies like requesting that students gave a thumbs up or thumbs down reaction to gauge understanding or to maintain engagement were helpful but no substitute for physically being able to see their work. More additional technologies than before were used like visualisers or self-made video clips to aid demonstrating tasks like drawing. These have been very useful and teachers are likely to continue using these methods. Other elements of online platforms like 'Teams' and 'Google Classroom', such as the class files and assignments features, may also stay as it is easier to track work and respond to students through this.

Both of the schools, once comfortable with this way of working, started to use the platform for wider benefits. In Deborah's school, Catering teachers offered 'family cook alongs' in the evenings. At the allotted time one teacher demonstrated the cooking method and the other fielded questions and indicated pace to the one demonstrating. At its peak, 107 students and their families joined. Daniela also stated she felt incredibly lucky to be part of a department (and school) where pupil engagement was good, and at times, it felt like things carried on as normal in their 'bubble'. Textiles students worked hard on their entries for *The Young Designer of the Year* (a national competition); Food, Preparation and Nutrition students had their weekly Cook-a-longs; and Product Design students were busy working on their projects, such as the

eco-speaker, confectionery packaging, and in the sixth form (17-18 year olds), on their architectural models. For Daniela this had a really positive impact on her own wellbeing, knowing that students were 'hanging in there'. Activities such as these in both schools promoted Design and Technology, community spirit and provided a break from the potentially monotonous routine of online learning, potentially improving the students' wellbeing and highlighting the 'above and beyond' attitude of Design and Technology teachers and scope of the subject.

Both schools report that whilst elated to be back in school they believed the students (and staff) had done incredibly well and were extremely proud of the way they had utilised online learning in the most positive way.

A note of caution going forward however is that the lines between home and work become blurred. This is sometimes helpful as the ability to work from home creates a better home, work balance but other times it can create the expectation that you are always available and boundaries need to be set.

Creative teaching

Once back in school in September 2020 and then again in March 2021 students were contained in 'bubbles' to aid safety along with other measures such as wearing masks and social distancing. In Deborah's school this meant that each year group was allocated an area of the school with the intention that if segregated a single year group bubble could be sent home to isolate rather than the whole school, should a number of Covid cases occur. Therefore, for most, teaching and learning wouldn't be disrupted. Daniela's school also had a bubble system but could mainly carry on as normal apart from with practical work. Both online learning and bubbles created unique problems for practical subjects like Design and Technology that required creative solutions.

Deborah reported that Design Technology provided the opportunity to break from the standard routine they had of logging on and completing a task at the computer for five to six hours straight. For example, one task set a treasure hunt asking students to find plastic items around the home and then analyse them. As the school is in a rural area another asked students to go into their gardens to take photos as research for design tasks. Others were making tasks, again mindful that some students lacked resources, even as simple as coloured pencils, so a variety of responses were allowed.

The making tasks were quite thought provoking to Deborah in that lessons had previously followed a rigid structure to ensure skills were achieved and to aid assessment. Whilst they included an element of creativity, essentially they were asking students to make identical products that demonstrated a particular focus or skill. She became aware that in meeting the objectives and assessment criteria a lot of the creativity had been stamped out of the subject. It is obviously important to ensure skills are achieved, but the results from being more open were interesting. For instance, an architecture project allowed a variety of responses including Minecraft as well as hand drawn and modelling from whatever students could find to complete it. The task gained a high level of engagement and enthusiastic responses. As Deborah's school considers next years' lesson planning an open ended task that can be completed in the students preferred way will certainly be part of it.

Teaching in bubbles caused different problems. Restrictions meant that group work and practical lessons were generally off limits. Safety guidance meant we could ensure that students were still able to learn subject knowledge, but practical work was difficult. Not easy when a significant amount of the subject involves practical work. For exam years in particular, research was well underway, with the impending development and modelling stage almost upon them, where they would want to use tools and equipment to explore possible solutions to their design ideas. Although many of the national examination boards later removed the practical element from the requirements, it brought with it complications in how do you judge the practical ability of a student when you can't make anything. Deborah's school continued in a limited way with practical tasks as these were vocational rather than academic qualifications and the practical tasks hadn't been removed from the requirements. It brought with it a whole host of difficulties. What practical tasks could and couldn't be completed in a maths classroom? Can resources fit on a trolley? How is equipment going to be sanitised between bubbles? How are you going to get equipment to the classroom as you might be running from one side of the school to the other whilst the students only have to move a few metres. Mostly more specialist tasks needed to be put on hold as even if the year group was in a workshop many rules needed adhering to. It wasn't impossible, just very difficult as it all took additional time and preparation. We also needed to mindful that some students were fearful of being in school and a more active environment made their anxiety worse. For Daniela the return in March 2021 brought with it an easing of practical restrictions, reflecting that she was 'delighted that practical was able to recommence, giving a little more of our subject identity back. "The sound of the drill, the noise of the laser cutter and the musical tone of the 3D printer setting up was so good to hear". In Deborah's school the disparity in experiences continues as the restrictions remained in place, with possible talk of a return to practical spaces in the final six weeks of the school year at the earliest. The differences also continue for individual students and staff as some are sent home to isolate and need to switch between online and face to face learning quickly. Daniela reports that 'being a mother of three primary school aged children was also a challenge (as well as having a husband who is a senior leader) as two of them had to isolate due to positive cases in their bubbles. Daniela was more lucky as her school were so supportive, and allowed her to teach lessons from home, virtually, to the students in school. This actually worked really well, and she will be forever grateful to the amazing cover supervisors who also helped manage things back in the classroom.'

Public Examinations

One of the most challenging aspects of teaching in the pandemic has been managing examination grading. Guidance from the government and examination boards was updated often and when, as Design and Technology departments in schools often do, they deal with a few different boards managing this information takes considerable time. However, making sure gradings were fair was another sizable challenge. The experience for students has been varied, some have had to stay home for shielding, others have not. Some have not coped well with the emotional side of the times we are in, others have. Some of the exam boards removed the practical elements, others have not. On the one hand this was necessary as practical work wasn't possible for the reasons above. On the other hand it has been important not to disadvantage the students who would have normally fared better in the practical element. This aspect was especially challenging as the exam boards have insisted that physical evidence is available to justify grades given if they ask for it. How to demonstrate the student's practical

ability without being able to make a product has been difficult to say the least. There was a move to teacher assessed grades and the way it has been done has brought with is a considerable amount of responsibility and stress. Deciding and collecting evidence for the given grades, along with the associated paperwork to ensure their validity and reliability has been exhausting.

Conclusions

It is undeniable that teaching in the pandemic has been extremely difficult and an experience that we doubt anyone would want to go through again but there have been positive elements. Networking for training and other purposes, between teachers and with the community has become easier as people have got to grips with video conferencing. Increased input from local business and external experts as the demands on their time has been reduced by not having to visit is certainly beneficial. Being able to open up enrichment opportunities for students and families that might not otherwise be able to, creates a good rapport between teachers, students and their families.

A chance to reflect on what and how we teach in the classroom has meant that some have changed their practices with a renewed focus on creativity and the opportunities offered to students.

Many talk about how this generation will be at such a disadvantage, and they have huge gaps of knowledge. However, there is a different side, in that this generation will be stronger in other ways; they will be more resilient, will be able to handle situations independently, learn to be happy in their own company, spend more time at home, and be better equipped for constant change.

There are hurdles that still need to be overcome, this game of Jumanji isn’t over yet. There are significant gaps in the students learning but teachers know what they are and what they have to do to fill them, exam boards are likely to make changes to their requirements for at least the next year and the virus hasn’t gone away. There is always the concern of another wave and another lockdown but teachers know they can survive it and they know how to support the students so the future, whatever it may bring, is more positive than before.

Using augmented reality (AR) in vocational education programs to teach occupational health and safety (OHS)

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Abstract
The aim of this research is to design a system that will raise awareness among vocational education students about occupational health and safety and the integration of Augmented Reality (AR) systems into the application/concept. Simply, projected on the work force surface, the AR system warns the students as they perform actions that pose a risk, need caution and may result in accidents. Therefore, by repetitive warnings, students learn the faultiness of actions in a faster pace and develop and insightful awareness. The research involves a literature review and two experiments studies in Çınarlı Vocational and Technical High School (CVHS) with high school and Dokuz Eylül University Mechanical Engineering (DEU ME) students. A system is designed according to the findings from these studies. As a result, students learnt to be more cautious, and the number of mistakes they make decreased. This will result in decrease in the number of occupational accidents, deaths and financial loss. The project presents an innovative method applicable both to the industry and the training a qualified work force.

Keywords
OHS training Vocational Education, Augmented Reality, Occupational Health and Safety, Education, Machining

Introduction
The problem that is stated in this paper tackles with the lack of courses and inability of the teaching of occupational health and safety (OHS) for vocational and industrial education. The great efforts of keeping the occupational health and safety standards high also makes the subject harder to teach. Without exposure to risky or dangerous situations, the workers may develop a false belief of being safe without precautions. Especially the inexperienced workers get injured more often. Otherwise, the worker becomes experienced and starts working as a form of a reflex, which may result in the false belief of being safe without the precautions. Although it is true that the inexperienced ones are the most likely to be involved in work accidents, experienced workers also make mistakes that result in injuries, or even death. Both employers and employees see OHS as a burden. Employers consider it a financial burden and time consuming because of all the inspections and training. The employees consider personal protective equipment needed makes them incapable of moving freely and consider training is not necessary.

This research has been undertaken to understand the effect of a fairly new technology on OHS training. The research phases are:

- Creating a guideline for industrial designers to start their research on OHS and augmented reality (AR) systems.
- Designing an education system to teach occupational health and safety in vocational schools.
- Creating a discussion on OHS and what can be accomplished about it.
- Understanding the effect of AR systems in the field of education.

Methods and Research Questions

This research consists of two parts; a preliminary study to understand the problem and its approximate solutions; secondly, a main study, the experiment of the developed system in vocational education. The main study had a systematic data collection and analysis, which made it available to be analyzed as both qualitative and quantitative research. The study's experimental and comparative data was examined with quantitative methods.

This experiment was a controlled field experiment with between-subjects design. Controlled experiments have control and test groups to find out the effect of the independent variable. Field experiments are experiments conducted in the field the person lives/studies/works in, in this case the educational field, vocational school. Between-subjects design is about changing one condition of the independent variable at a time. In the first experience, for example, vocational high school students of the same age and same year, and the only difference between the groups was the source of the warning in cases of violations. Between-subjects design is a commonly used method in education which requires at least 20 participants for each group. A broader study can be conducted with more participants. In such a study, types of warnings given by the machine can be investigated in terms of effectiveness.

The research questions were

- Are AR systems effective in OHS training and if they are effective, how effective are they?
- Can a system be designed for an existing machine to make it safer to operate?

Significance of the Study

This research clarifies the significance of OHS, guiding the designers into a different path and a way of thinking in order to design systems that help teach the students OHS.
OHS training has been a matter of professionals. It has been changing for a while. Even the Ministry of Education in Turkey has made it compulsory to employ OHS experts in every department. These experts inspect schools and other educational areas, such as courses, in terms of safety and have the authorization to take action in order to make education safe for the students, teachers and other people using these premises.

The main difference of this research is it does not rely on the technology or the innovations of the machines that makes them safer to operate, rather relies on the learnability of OHS in the early stages of professional life or even while studying.

The main difference between a person and this system is the system cannot be tricked, and it is always there, watching the mistakes, while teachers and inspectors move around to inspect

other students. It also cannot be hacked while most machines in small businesses are hacked by either the workers or the employers themselves in order to operate more quickly.

Limitations of the Study

The experimental design was conducted in CVHS. Although a lathe is used in many applications today in industry, most of the students at the high school do not get the necessary education to be a lathe operator and the demand for these courses are decreasing every year. Because of that, the test was conducted with 14 high school students as participants. In order to increase the number of subjects, DEU ME students were included in the study as a second experiment. The suggested system is intended to be used for educational purposes; therefore, it has been tested with students only. However, as a further study, it could be tested with professionals working with lathe machines.

Theoretical Background

According to International Labor Organization (ILO), OHS is the science of expectation, acknowledgment, decision and control of dangers emerging from the workplace or the work itself that has a negative impact on the health of the laborers.

Precautions and Losses

Preventing work accidents need a systematic approach exactly like preventing car accidents. Although legal regulations are effective methods, non-punitive methods are also used. The most important non-punitive methods are OHS education or training, Prevention through Design, INFO cards and checklists (Jørgensen, 2016). These applications are known as injury and illness protection programs. Safeguards in machines and systems that prevent the worker to get or reach into the dangerous zones have been found to be useful. For example, the number of injuries in power-presses decreased after the installation of two hand operating systems (Suokas, 1983). Similarly, accidents and injuries in lathe operations have decreased in great numbers with the improvement of lathe safeguards (Varonen, 1995). However, using safeguarded machinery is not legally obligated and accidents that could have been avoided by simple guards happen every day. Since legal precautions in Turkey are not specific enough, non-punitive methods are the primary type of precautions. They depend on the decisions of employers or managers.

Losses in work accidents are divided in two, human loss and financial loss. Most of the time human loss or an injury results in financial losses due to accident benefits given to the injured worker or in case of loss of life the worker’s family, stopping the manufacturing in a factory and long-term effects such as the workers’ unions demanding higher wages in order to work under dangerous circumstances. In addition to these, the employer of a high risked factory will not be able to find the workforce they need since workers would not want to work in a factory that has a bad reputation with OHS.

Occupational Health and Safety in Turkey

OHS gained importance in Turkey after the horrific accidents in Tuzla shipyards in 2008. Enforcement law regarding work accidents and occupational safety were accepted in the Turkish parliament with an omnibus bill afterwards. This law included the obligation to have the necessary training or education for dangerous work fields or jobs that require training in order

to work safely. Professional competence certificates obtained after education and training are given by the vocational qualification authority in The Ministry of Education.

EUROSTAT data shows that Germany, UK, Norway, Finland and Ireland have the least number of deaths at work, with numbers varying from 1.0 to 1.8 in 100,000 while it is 12.3 in 100,000 in Turkey. According to the data obtained from the report of The Social Security Institution of the Republic of Turkey (Sosyal Güvenlik Kurumu, SGK) in 2014, main metal industry and metal product manufacturing are the most dangerous economic activities in case of the number of accidents and the number of days spent in recovery. According to the Turkish Statistical Institute's (TÜİK) report on work accidents and work-related medical problems, most accidents happened among machine operators and assemblers with 4.8%, which is more than twice as much as the average of 2.3%. The same report states that the eye strain and visual focusing is a highly encountered problem among the workers, with 10.4% of all workers contributing the survey.

In order to teach safety in vocational education, in Turkey, 11th grade students are given at least 8 hours of OHS education at school. This course does have certification. Their education also includes a career development course in 9th grade, which also includes OHS education.

Vocational Education

Vocational education is crucial for developing countries. It provides qualified manpower. Vocational education costs 2 to 4 times more than the mainstream education (Psacharopoulos 1997). It also has a financial effect on the students, since they cannot work while having this education. However, this financial burden is paid back accordingly, since educated and qualified manpower earn a lot more than unqualified workers. The important issue in this matter is not losing qualified manpower due to an accident. This can be achieved through giving proper work safety education to these people during their time in the vocational education.

In Turkey, students with the lowest high school entrance exam grades apply to vocational schools. Going to a vocational school is mostly not a choice of the student but an obligation in order to continue their education. The choice of vocational schools is not made by the students since they do not know their fields of interest nor do they know themselves completely. This choice is made with the guidance of the parents, the grades they achieved in the exams and their success in courses before (Hepkul, 2014). According to a study implemented with vocational high school students in Bursa, Turkey, these students see themselves capable of understanding technical and mechanical matters although they think that they are incapable of the social skills (Bağatır et.al, 2004). This also shows their sense of self is affected by their education and their choice of high school.

According to Andersson et al. (2015), vocational school teachers teach OHS based on their own experiences. They found that only a small percentage of teachers search for teaching materials for this subject. This kind of education bases itself on the risks; teachers warning the students according to what have happened to them in their professional life or their own training phase. This type of education lacks pedagogical methods, therefore may result with the student not understanding the subject. Andersson et al. (2014) found that an OHS education based on teacher's experience results in the student believing they are the only responsible people and the key to avoiding accidents.

Augmented Reality

AR enables us to attach computer generated elements from the virtual environment into the real world (Graham et al., 2013). Technology and computer science enables us to go beyond our limits of visual perception through showing us the world with the information which was not there before.

AR is used in many fields from education to tourism, medical applications to military. Research has been done by Serio et al. (2013) on the effects of augmented reality in education. In this research, students claimed that these methods are more stimulating than the traditional education methods. Other researchers have supporting these results: use of AR and sensors is effective for awaking students' attention (Enyedy et al. 2012; Kamarainen et al. 2013). AR enriched textbooks are proven to catch students' attention, make the class more enjoyable and arousing the curiosity for the courses. However, AR's use in education is limited to the enrichment of the teaching materials. According to the predictions made by Abdoli-Sejzi (2015), it will be used in OHS in the future.

Experimental Design

This study consists of two experiments and their results; an experiment conducted with the high school's students in May 2016 and a second experiment with DEU ME students who have completed their second semester in August 2016.

Case studies were implemented in order to find out what can be done to increase occupational safety without changing the setups of the machines or the workplace and without adding extra safety materials or machines other than the ones in use. While working on the system implementing the experiment, data to understand the workplace hazards was gathered by photographing and interviews with teachers of the vocational school. This data helped us to understand how accidents can be avoided in such environments where the operators are not professionals. This data also helped us make guidelines to make better machines in terms of safety. Further information regarding this matter will be given in results and conclusion chapters.

Population and Sample

Students who participated in the test were chosen randomly among the technical high school students and industrial high school students. 14 students were randomly divided into two equal numbered groups. The first group, which was the test group, used the test setting and got the warnings from the machine rather than the teacher. The second group, which was the control group, did not use the test setting and the students were warned by their teacher when they make mistakes. Both groups' mistakes and the incidence frequencies were noted down. A week later, the same students were gathered again, this time without the test setup. Their mistakes were noted down again. Both weeks' results were compared in order to see if the system has made a difference in the behaviors of the students.

The experiment was repeated with DEU ME students as a second experiment. 28 students participated in this second study. All steps of the previous experiment were repeated.

Students were expected to machine the parts given to them by their teachers as a part of their term projects, for university students, parts given by their instructor and the experiment was implemented while they were machining these parts. All parts and tasks given to the students were similar.

Experimental Setup

The device planned to be used is an autonomous device, meaning it will decide if the student is making a dangerous move or an action and warn them accordingly. These dangerous actions and violations are identified according to the observations of vocational school teachers, directly reported to the research team. They stated the most common mistakes made by their students, that are dangerous in terms of OHS.

Although there are many options to automatize this device, the most effective option would be machine learning. The first reason for choosing this method is that it takes less coding, and any dangerous move can be added to the system easily even after the setup has been finished. This would be helpful if another dangerous action was spotted among the students or if there is a fault or a missing part in a machine that the students need to be careful of. Matters of programming the final system will not be explained further. Examples of this kind of system in Turkey can be seen in portfolio of “Hedef Sıfır” (Aim: Zero) projects, which aim to end occupational fatalities. They produce machine learning based OHS systems with cameras as input devices. These cameras send the information to a computer which detects a hazardous move or action and warn the worker or even shuts down the systems. Another project of this group detects a worker’s outfit to find out if it is correct for their line of work, with safety guards and equipment. This system also works with machine learning, for teaching the computer which kind of visual is the correct and if the computer does not perceive this image, it gives a warning. Unfortunately, these projects are inactive today and the term “Hedef Sıfır” (Aim: Zero) is used in environmental sustainability matters in Turkey.

Other violations that cannot be detected by such systems can be detected via attaching other cameras to the system. These types of systems are available. A system that can detect if the worker is wearing appropriate Personal Protective Equipment (PPE) is made by the Hedef Sıfır project, mentioned before. Also, other companies have similar systems that can detect the missing or not appropriate PPE by cameras that feed a computer and AI detecting these mistakes. Such system can ban the worker from worksite, or if it is connected to our research’s system, it can either give a red-dot warning or even can shut the machine down if the violation continues.

Software used in the prototype, called “red-dot” named by the programmer, is programmed for this project. This software is designed with Unity Software Development Kit. It enables the user of the computer or a smartphone to put a red dot on the screen where they click or touch, depending on the device. The red dot on the screen can be erased after the student realizes and corrects their mistake. With this software, the prototype was controlled by the researcher and the warnings were projected on the working surface by the projection device hanged above the lathe. The color of the light in this prototype was chosen according to the accepted color norms in machinery; as for blue machines having orange warnings and green machines having red warnings, due to the negatives of the colors. Most of the lathe machines in CVHS are green with some exceptions of blue. This system was tested on a green lathe. Additionally, the

software can produce warnings of different sizes, for example, a small dot is needed for a precise warning and a big red dot for getting too close to the machine which can happen really quickly and is a whole-body mistake.

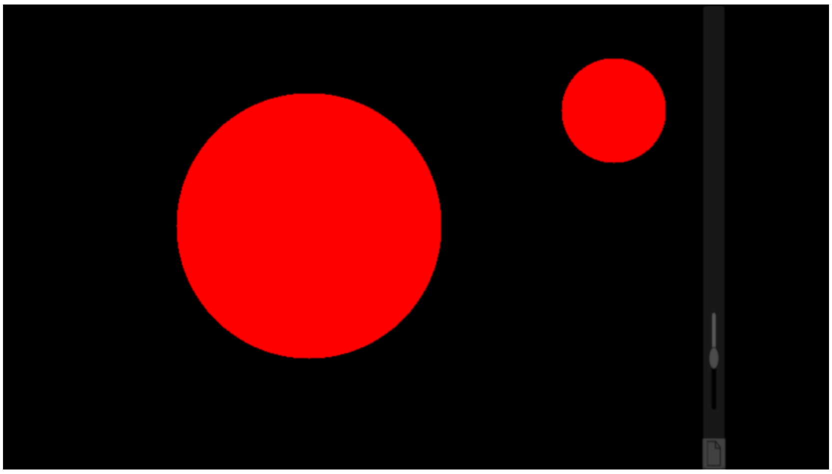

Figure 1. Screen capture of the Red-Dot Software

The projector used is chosen according to the uncontrollable lighting conditions in the workplace. The projector has to have high lumen value in order to be visible in the highly sun-lit workshop.

Figure 2. Experimental setup in CVHS

Figure 3. Warning seen on chuck

Final product is intended to be encased and will consist of the following parts:

- Single Board Computer
- Camera
- Sensors
- Smartphone
- Projector
- Case

The block diagram of the prototype and the system are presented in Figure 4 and Figure 5, respectively.

Figure 4. Block diagram of the prototype used in the experiments

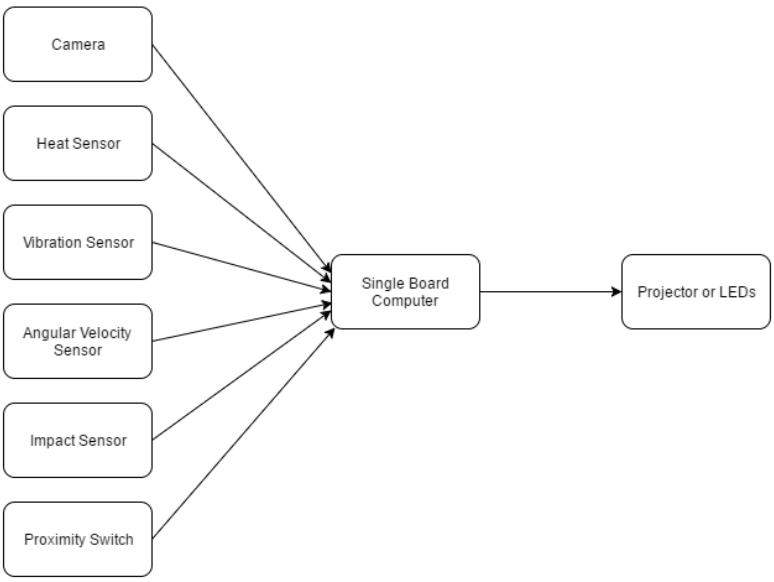

Figure 5. Block diagram of the system

In the experiment, the manual input of warning is done by the researcher. However, students in the test group did not receive direct warnings from the researcher nor from their teachers. As

seen in the block diagrams of both the prototype and the system, the prototype is researcher-dependent while the system will be independent.

The real system will have, cameras, heat, vibration, velocity, impact sensors, proximity switches. Cameras will be used as intelligent systems to detect the hazardous movements such as standing too close to the machine, having people around the machine other than the operator, leaving a workpiece, key etc. unattended.

The testing setup was intended to have a camera to record the hazards and movements of the student but due to nervous behavior of the students and their unwillingness to be recorded while working, the camera was detached from the device. Recordings were done with another camera for some of the students. During the test and also during the no test setup in the workshop, students' behaviors, hazardous moves, hazardous actions and surroundings, simple mistakes that are not hazardous by nature, were observed and noted down.

Photography was another method used to gather data, especially when the student continues to make the dangerous action. This method was also used to gather data around the workshop in order to find the mistakes made about occupational health and safety in terms of surroundings and machinery.

Data collection was made throughout the days; the experiment was not implemented in a specific time of the day.

Data Analysis

Data gathered from the 2 days of studies with each group of students were organized as day 1 and day 2; on the first day, control and test groups, without and with the system operating respectively; on the second day both test and control groups worked without the system. Again, their mistakes and hazardous/risky actions were noted down. Data was analyzed in order to see if the system is an efficient method of teaching high school students about OHS and the problems that are confronted. Data was obtained with between-subjects design. In this type of experiments, only one independent variable is changed. In this experiment's case, this variable is the source of warning.

Findings and Results

The information and insight gathered with the literature review suggested that most of the accidents are avoidable through taking proper precautions and with the use of required personal protective equipment.

The test group of high school students showed positive reactions to the system. Their first reaction was investigating the system by putting their hands in front of the projector and asking questions about it such as "does this record our actions" or "will this affect our grades?". After gaining their trust they began to work with the system on, without further concern.

The test group students did not repeat their mistakes. Four out of seven of them did not make any mistakes again. Every one of them started using safety goggles after being warned by the system. However, one of the students failed to understand the hazards caused by the tool bit.

He did not remove the unused tool bit and did not tighten the tool bit and got warnings from the system both times. Even when he did not do the exact same mistakes, he cleaned the tool bit with his bare hands, without thinking about the consequences. This shows that such systems will need upgrades in order to teach the dangers of a certain part. A positive reaction towards the system was from another student, who was in test group. He warned his friends about the importance of the safety goggles after being warned by the system. He even asked his friends, who were watching him while he was operating the machine, to put their safety goggles on.

Students in the control group did not put their safety goggles on even when they were warned by their teachers multiple times. They continued working without safety goggles and without a closing chip shield, which was extremely dangerous. Eventually, an incident happened during the experiment and a student had a flying chip get into his eye. Luckily, no permanent damage was done, however, he continued working without the safety goggles even after this accident. Another student in the control group, failed to understand the dangers of getting his limbs close to rotating parts and standing away while the machine is working. He did similar mistakes both days. Another student measured the work piece without getting the tool bit away both times, which indicates he did not learn from the warnings made by the teachers. Another student held the work piece with bare hands and burned his hand the first day, did not need warning from the teacher but he learned from his mistake and did not hold the hot piece next time, but he made his friend to do so, which indicates that he lacked discipline and failed to understand the consequences of his actions. Another student in control group made exactly the same mistake both days. He left too many tools on tool kit platform. Even when he was warned, he made the same mistake, failed to understand how these tools could cause hazard.

None of the control group students avoided all incidents on the second day. This showed that the system is an effective method of warning the students. The study also indicated that the students do not listen to their teachers' warnings as much anymore. The students did not change their attitudes for the safety gear even after the teachers warned them. This may be the result of the teachers not using this gear too.

DEU ME students made different mistakes than CVHS students. The main mistake made by university students were forgetting to use safety goggles and chip guards. Difference in these two experiments can be explained by the students' level of expertise in terms of machining; none of the DEU ME students had worked on lathe before the first day of the experiment. Therefore, the level of difficulty of the work pieces given to them was much lower than the vocational education students. However, the teachers at vocational school call these students fast learners. Although they did not have OHS training at school, yet these students were more aware of the hazards.

Safety goggles were not used by 12 of 28 DEU ME students, this being the most common mistake by 32%. Either the machine or the teacher warned some of these students more than once; one of them was warned 4 times. Total warnings for the goggles were 20. However, only 2 students in test and control groups forgot to use safety goggles on the second day.

The second most common mistake made by university students was about their outfits. The mistakes about outfits were not wearing a smock/work uniform, not buttoning up the outfit properly and wearing jewelry on their hands.

The least common mistake in both groups was accidental start-ups which occurred only twice, which equals to 3%. Standing close to the non-operating machines was the second least common mistake. Four warnings had been made for standing too close to the machine.

Chip guards were not used by 8 out of 28 and these students had been warned only once. None in the test group forgot to use the chip guard on the second day.

In order to understand the effectiveness of the system in both groups, having different number of subjects, the average of mistakes made by students have been systematically adapted into a graphic where test and control groups in both experiments can be seen in the same image.

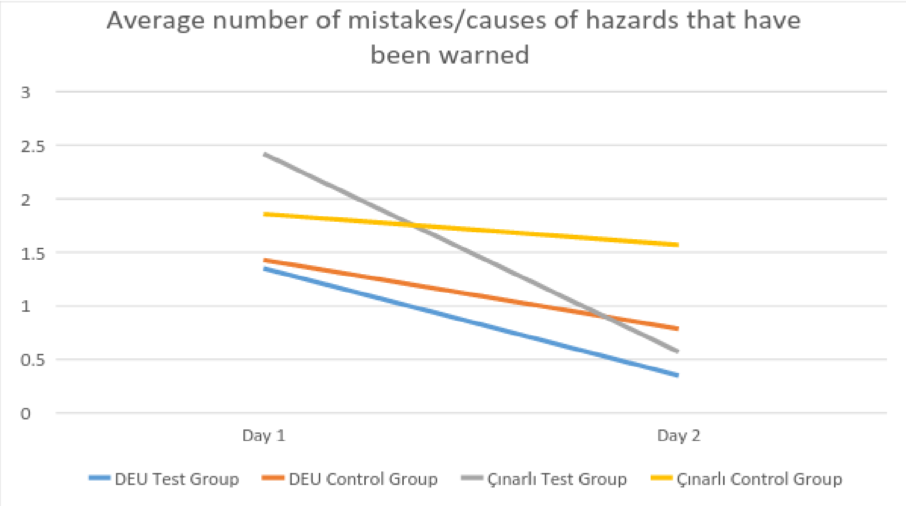

Figure 6. Average number of mistakes/causes of hazards that have been warned

The graphic in Figure 6 shows the average number of mistakes/causes of hazards that were warned either by teacher or by the system. Day 1 shows the first day of the experiment. Day 2 shows the second day of the experiment. Warnings did not take place on Day 2, only students' errors were noted.

The average number of mistakes was higher in CVHS students than DEU ME students. The decrease in the number of mistakes between Day 1 and Day 2 had been expected. The incline of the graphic shows the degree of effectiveness of the source of warning, either it is the teacher or the system. This graphic shows that in both experiments, the average number of mistakes decreased both in test and control groups.

The most drastic change, however, is seen in the test group of CVHS. In both experiments, this test groups made fewer mistakes than the control groups in their second days.

Final Design of the System

As final design, a system without built in projection, is considered to be more cost efficient and more applicable for schools in Turkey since the government supplies every school with projectors.

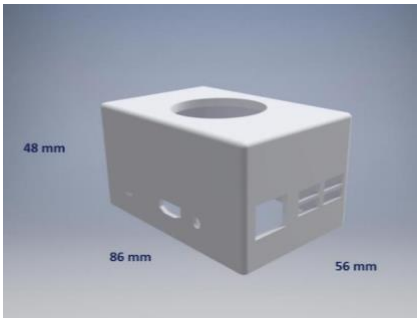

Figure 7. Case design for the system

In cases of a low budget, the system will be installed in one, or a few lathes; the students in that workshop will work on that lathe by turns. As mentioned before, with additions to the software, this system can work on any machinery, so this system can be demounted from the lathe when all students have been trained with it and can be mounted on another piece of machinery such as milling machines or bench drills. This system can also be used in factories or workshops. With this system, OHS inspection can be made easily by switching the “red dot” warnings off.

If there will be more than one machine in a machine park with systems connected to them, these systems will also be connected via wi-fi or ethernet. A sensible option would be to connect all the inputs (sensors, cameras etc.) to a main computer with higher computing power. This would result in a smaller box for each machine, easy management of the system, better and faster machine learning.

Conclusion

OHS trainings and machinery used in the school lack safety and the teachers’ warnings are found to be not effective enough on the students. These teenager students’ attention is hard to catch since they did not choose to be in vocational high schools in the first place. However, new technology caught their interest with this system. Future methods of education in vocational schools should depend more on technology.

The system designed to teach vocational education students and mechanical engineering students is found to be efficient and taught students about OHS and it enabled the students to understand the hazards caused by specific parts of the machine. With the use of the system, the average of the mistakes made by students dropped significantly. The biggest decrease was in CVHS; from nearly 2.5 mistakes to 0.5. In both experiments, high school students and mechanical engineering students, the test groups had more reductions in the number of mistakes per person than the control groups. This confirms that this system is more effective than the warnings coming from the teacher and was most effective on high school students, who are with their teachers all year.

AR is found to be effective for an education system and spatial AR is found to be cheap and applicable in vocational high schools since these schools lack budget and cannot afford expensive systems or cannot afford to change all their machinery.

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References

Abdoli-Sejzi, A. (2015). Augmented reality and virtual learning environment. *Journal of Applied Sciences Research*, *11*(8), 1-5.

Andersson, I.-M., Rosèn, G., Åberg, M.M., & Gunnarsson, K. (2014). Knowledge and experiences of risks among pupils in vocational education. *Safety and Health at Work*, *5*(3), 140-146.

Andersson, Ing-Marie, Rosèn, G., & Gunnarsson, K. (2015). Role of headmasters, teachers, and supervisors in knowledge transfer about occupational health and safety to pupils in vocational education. *Safety and Health at Work*, *6*(4), 317-323.

Bağatır, S. & Peker, R. (2004). Endüstri meslek lisesi öğrencilerinin yetenek ilgi ve değerleri ile okudukları bölümler arasındaki ilişki. *Journal of Uludag University Faculty of Education, 17*(2), 329-340.

BS OHSAS 18001 - Occupational Health & Safety. BSI. (n.d.). http://www.bsigroup.com/en-GB/ohsas-18001-occupational-health-and-safety/.

Di Serio, A., Ibáñez, M. B. & Kloos, C. D. (2013). Impact of an augmented reality system on students' motivation for a visual art course. *Computers & Education*, *68*, 586-596.

Enyedy, N., Danish, J. A., Delacruz, G. & Kumar, M. (2012). Learning physics through play in an augmented reality environment, *International Journal of Computer-Supported Collaborate Learning*, *7*(3), 347-378.

EUROSTAT. (n.d.) 2007 *Ölümlü iş kazaları oranları*. http://epp.eurostat.ec.europa.eu/

Graham, M., Zook, M. & Boulton, A. (2013). Augmented reality in urban places: contested content and the duplicity of code. *Transactions of the Institute of British Geographers*, 38(3), 464-479.

Hedef Sıfır. (n.d.) http://www.hedefsifir.com

Hepkul, A. (2014). Meslek Lisesi Tercihi Sürecinin Keşifsel Olarak İncelenmesi. *Anadolu University Journal of Social Sciences*, *14*(2), 41-52.

Hülagü, R. (2016). *Using augmented reality in vocational education programs to teach occupational health and safety* (Unpublished master's thesis). Izmir Institute of Technology, Izmir, Turkey.

İş Sağlığı ve Güvenliği Kanunu. (n.d.) http://www.mevzuat.gov.tr/MevzuatMetin/1.5.6331.pdf

Jørgensen, K. (2016). Prevention of simple accidents at work with major consequences. *Safety Science*, *81*, 46-58.

Kamarainen, A. M., Metcalf, S., Grotzer, T., Browne, A., Mazzuca, D., Tutwiler, M. S. & Dede, C. (2013). EcoMOBILE: Integrating augmented reality and probeware with environmental education field trips, *Computers & Education*, *68*, 545-556.

Psacharopoulos, G. (1997). Vocational education and training today. Challenges and responses, *Journal of Vocational Education and Training*, *49*(3).

Smartphones - Statista Dossier. (n.d.) *Facts and statistics about Smartphones* https://www.statista.com/study/10490/smartphones-statista-dossier/

Sosyal Güvenlik Kurumu. (2015). İş kazaları ve meslek hastalıkları istatistikleri 2014.

Suokas, J. (1983). The effect of power-press regulations in Finland. *Journal of Occupational Accidents*, *5*, 1-8.

Türkiye İstatistik Kurumu. (2014). İş kazaları ve işe bağlı sağlık problemleri araştırma sonuçları 2013.

Varonen, U. (1995). Safeguarding of lathes and occupational accidents. *Safety Science*, *21*, 15-22.

ePortfolios in craft education at the primary level: Teachers' experiences on ICT integration

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Abstract
The Finnish National Core Curriculum (NCC), which took effect at the primary school level in autumn 2016, includes ICT competence for all school grades, and encourages pupils to document their working processes in crafts. However, the literature provides evidence of the barriers faced by teachers in integrating information and communication technologies (ICT) into teaching. This paper is shaped as an autoethnography, and its purpose is to share the challenging experiences of primary school teachers involved in the integration of technology in an electronic portfolio (ePortfolio) project in craft education with 43 third-grade pupils in a Finnish primary school context. Research data – field journal notes, video recordings and interviews – were analysed qualitatively, relying on Ertmer's conceptual framework on ICT barriers (1999) and five main categories were reported, which are 'Inadequate software/hardware', 'Learner group attributes', 'Allocation of responsibility', 'Lack of resources' and 'Teacher attributes'. Based on the results, the study discusses the challenges of integrating ICT into craft education in primary level.

Keywords
ePortfolio, primary school, digitalisation, craft education, ICT barriers, multimodality

Introduction
The aim of the present study was to examine the challenging experiences of primary school teachers involved in the implementation of information and communication technologies (ICT) in craft education. Digital documentation, in the form of electronic portfolios (hereafter ePortfolios), was conducted by third graders based on their crafts artefacts. Craft education, an obligatory school subject in Finland, is an important part of Finnish basic education and has a 150-year long history in the Finnish school system (Saarinen et al., 2016). According to the Finnish National Core Curriculum (NCC) for Basic Education, the subject craft education in comprehensive school encompasses various techniques, such as sawing and crocheting, technology education, and design (NCC, 2016, p. 434). Furthermore, the craft education contributes to implementation of digital documentation, since the NCC (2016, pp. 436-437) encourages pupils to use the digital technology, and to document their working processes.

An ePortfolio at simplest is an electronic collection of authentic evidence showing one's learning journey (Barrett, 2010; Lorenzo & Ittelson, 2005). According to Nicolaidou (2013) ePortfolios show great potential in supporting students' writing performance and facilitating peer feedback. An ePortfolio can have various roles in schools, including as a storage space for documentation, an assessment tool, a peer feedback channel and a process- and development-reporting tool (Saarinen et al., 2016; Nicolaidou, 2013). The empirical research on using ePortfolios has so far focused on secondary and higher education levels, whereas ePortfolio use in primary level education is limited (Kuan-Cheng et al., 2006; Nicolaidou, 2013). Furthermore,

only a few studies have focused on usage of ePortfolios in primary level craft education. Saarinen et al., (2016) have studied pupils' experiences using ePortfolio method in primary level craft education, and Saarinen et al., (2019) concentrated on the content of the ePortfolios, likewise, in primary level craft education. More studies are needed to confirm skills and knowledge needed in ePortfolio creation at each age (Saarinen et al., 2019). Furthermore, teachers' experiences in this kind of research setting are rare.

In this autoethnographic study, I investigated an ePortfolio project for third graders (pupils aged 9–10 years), in which the pupils created digital multimodal content in the form of ePortfolios based on their crafts artefacts, using desktop and tablet computers (Apple iPads) in a classroom setting in southern Finland. Multimodal content refers to different semiotic and sensory modes, such as written, visual, spatial and auditive elements (Sefton-Green et al., 2016; Dix et al. 2004). Multiliteracies is an approach that highlights the aspect of multimodality in texts (New London Group, 1996; Cope & Kalantzis, 2009; Kress, 2003). Multiliteracy is also included in the NCC (2016) as a transversal competence, and it means the 'abilities to obtain, combine, modify, produce, present and evaluate information in different modes, contexts and situations, and by using various tools' (NCC 2016, pp. 33-34).

Digital technology is widely used in our society and, consequently, the use of ICT in teaching and learning has been one of the main goals of Finnish education policy over the past ten years (Hoikkala & Kiilakoski 2018; Tanhua-Piiroinen et al., 2019). So far, according to Hoikkala and Kiilakoski (2018), attempts to integrate ICT have had a common main challenge: integration has mainly been driven by the central administration, which neglects pedagogical aspects such as teachers' everyday schooling expertise and students' personal digital culture. ICT usage levels in Finnish schools have fallen short of the target (Hoikkala & Kiilakoski, 2018; Tanhua-Piiroinen et al., 2019; European Commission, 2013). Yet another attempt to boost integration of ICT in teaching and learning is the current Finnish National Core Curriculum (NCC) for Basic Education, which includes ICT as a transversal competence for all school subjects (NCC, 2016). Nevertheless, the ICT competence targets are expressed on a rather general level in the NCC, and no dedicated hours are given for ICT; rather, it is to be integrated into all learning (NCC, 2016). The NCC (2016) took effect at the primary school level from the 2016–2017 school year. The reality of teachers is twofold in relation to school digitalisation. On one hand, the NCC (2016) obligates extensive use of digital technology in schools. On the other hand, there are several challenges, known as ICT barriers, impeding technology integration in everyday schooling (Admiraal et al., 2017; BECTA, 2004; Hew & Brush, 2006; Ertmer, 1999).

There is evidence that teachers find it problematic to fulfil the digitalisation requirements of the NCC for various reasons. These reasons include a lack of digital resources (software-, hardware- or network-related), low quality of digital strategies in schools and a lack of support for teachers in fulfilling the requirements (Hoikkala & Kiilakoski, 2018; Tanhua-Piiroinen et al., 2019; European Commission, 2013). Similar results are presented in the literature, such as by Vanderlinde et al., (2015), who identify the individual-teacher-level variables (e.g. ICT competence and professional development) and the school-organisation-level variables (e.g. ICT leadership and school vision) in their study concerning the conditions that support or hinder ICT use in primary schools in Flanders, Belgium. Konstantinos et al. (2013), for their part, report 'a wide and acute confusion among the ICT teachers' which manifests in difficulties for the

achievement of a horizontal approach to ICT and in limited cooperation between ICT teachers and other teachers in primary schools in Greece. Yuksel et al. (2013) conclude in their longitudinal survey of Turkish primary school teachers from 2005 to 2011 that the most significant barriers to effective ICT integration are the lack of and limitations of the hardware. Thus, a fair amount of literature provides evidence of the barriers to ICT integration in educational setting in general, but there is a knowledge gap regarding empirical evidence from research looking at sector or subject specific barriers restricting the use of ICT within the youngest age groups in primary education (e.g. BECTA 2004).

Technology should be a natural part of everyday school life (Blau & Shamir-Inbal, 2017; Kirschner, 2015), which is not necessarily the case in the 'messy realities of digital technology use in 21st century school systems' (Selwyn, 2011, p. 25). These messy realities caught my attention during the third graders' ePortfolio project.

In this study, I seek to contribute to the principled understanding of primary school ICT barriers (see above Konstantinos et al., 2013; Vanderlinde et al., 2015; Yuksel et al., 2013) by exploring them in the context of craft education. By means of the rich data of an autoethnographer and authentic quotes in the findings chapter, I aim to describe in detail the problematic endeavour of my colleagues and me to integrate technology into our teaching in order to meet the requirements of educational policy. I centre my research around the following research questions: From teachers' point of view, what barriers impede technology integration in ePortfolio lessons, in primary school craft education? How do these barriers appear at the micro- and macro-levels?

Ertmer's conceptual framework for analysing ICT barriers

In this study, I use Ertmer's (1999) identification of first- and second-order barriers as a structure that guides my investigation of ICT barriers in a Finnish primary school context, in craft education. First-order barriers, considered extrinsic to instructors, as Ertmer (1999) defines them, refer to missing or inadequate resourcing, such as a lack of resources, limited time and a lack of technical support or access to appropriate training. Second-order barriers, considered intrinsic to instructors, are instead rooted in the beliefs and value systems of individuals, such as beliefs about teacher–student roles or teaching methods, established classroom practices and attitudes such as unwillingness to change.

First-order barriers are eliminated mainly by securing additional resourcing, whereas confronting second-order barriers demands challenging one's belief systems and the routines of one's practice. This conceptual framework of Ertmer has influenced numerous researchers and has been used in analysing why instructors fail to integrate technology into instruction at various levels of education (Admiraal et al., 2017; BECTA, 2004; Hew & Brush, 2006; Yuksel et al., 2013).

Context for the research

School context

The research was carried out in two separate third-grade classrooms in a suburban comprehensive school, Owl School, in southern Finland, in the 2016–2017 school year. In this year, Owl School was attended by approximately 800 pupils, ranging from pre-school to ninth

grade. Basic education in Finland is non-selective, and every pupil is allocated a place in a nearby school. Finland has low levels of stratification in its education system, which means that no class enjoys more advantages than any other (OECD, 2012). Written permission for data collection was sought from both the city municipality and the school principals.

Teacher participants

As a researcher, class teacher and crafts teacher, I started a multimodal ePortfolio project with my own class and asked two other third-grade class teachers, Lisa and Tina (pseudonyms used for teacher participants), to join the project with their classes. Additionally, I invited all the teachers teaching crafts to Lisa's and Tina's pupils to join the learning project and received the consent of every teacher involved for participation in the study. Lisa wanted to commit to ePortfolio creation with her pupils, whereas Tina and crafts teachers Sally, Mary, Cathy and Vicky wanted to join tentatively, without strict obligations to produce anything additional with the pupils. Thus, Lisa, with almost 30 years of teaching experience, became the key informant for my study, alongside me, with my five years of teaching experience. I worked in close cooperation with Lisa throughout the entire project and offered her help and guidance at different phases, often in the form of simultaneous teaching. The other teachers mentioned above made small contributions towards the project goals, such as using 1–2 lessons for documentation activities with their pupils, but their contribution was non-committal. Nevertheless, Tina, Cathy and Sally provided me with useful opinions and ideas throughout the school year in collegial discussions. Most of the research data and findings are based on my observations as a researcher-teacher, but Lisa's contribution has been remarkable.

Pupil participants

The pupil participants of the study were 43 third-grade pupils, aged 9–10 years, of two intact classes (my class and Lisa's class) in a primary school. My class consisted of 11 boys and 12 girls, and Lisa's of 12 boys and 8 girls. The aims of the study were explained to all pupils and their parents, and both the pupils and their parents were asked for a written permission to conduct the study. Both classes had used iPads at school several times during the 2014–2015 and 2015–2016 school years, mainly for maths and (Finnish) language-related learning games. Lisa and I had not used desktop computers with our pupils before the 2016–2017 school year.

Digital learning environment

The first fifty iPads introduced in Owl School during the 2014–2015 school year. Since then, digitalisation at the school has progressed, and at the beginning of the 2016–2017 school year, every teacher had a laptop, and there were over 100 iPads available for the pupils. There was a need to choose a digital learning environment for Owl School, as Finnish municipalities had launched a service called 'Edustore' for digital learning content acquisition and downloads, and an environment supporting the Edustore service was required. This was when Peda.net came along.

Owl School began using Peda.net's school network, an online service for pedagogic purposes, at the beginning of the 2016–2017 school year. The Peda.net service, coordinated by the Finnish Institute for Educational Research at the University of Jyväskylä, contributes to ICT usage in education by offering its members online tools to be utilised as schools' homepages and virtual learning environments. The service consists of organisational sites and personal profile spaces.

We teachers, in cooperation with Owl School principals, decided that Peda.net was to be used with primary school pupils. We were allowed to choose between Peda.net and another digital environment, Moodle. Peda.net, based on a short introductory training session, seemed easy to use and it operated on various types of end-devices, such as desktops, tablets and phones. The non-profit organisation behind the product, as well as the fact that the tool is widely being used in Finnish municipalities at different levels of education, also influenced our decision. As stated by Selwyn (2011, p. 33), digital technology in schools often just comes in: decisions are made by nonteachers, often as a part of national school technology policies, and the needs of teachers and pupils are not necessarily considered. In Owl School, even though the teachers participated in selecting the tool, there was not much choice. It was not possible to organise proper testing of the tool or benchmarking of the available systems since there was neither the time nor the competence available to carry this out.

ePortfolio project in crafts at Owl School

My intention was to construct an ePortfolio project for third graders which would include experimental learning and the integration of ICT in craft education. I also wanted to reflect on the requirements of the NCC, which places a strong focus on ICT competence and multiliteracies (NCC, 2016). I planned a project in which two classes of third graders, including my own, would familiarise themselves with Peda.net and learn to use ePortfolios as a process- and development-reporting tool in craft education.

In digital documentation of their crafts artefacts the pupils produced multimodal texts (Sefton-Green et al. 2016; Dix et al. 2004) in Peda.net combining visual photos and written texts. Figure 1 and Figure 2 present examples of two third grade pupil's ePortfolios. The pupils have designed and produced a potholder and a tuned coat hanger and explain the work processes in their ePortfolios. The text samples are translated from Finnish to English.

First, I used the sewing machine to overlock the edges of two denim pieces with zigzag. Second step was decorating one of the denim pieces with different stiches. Third step was attaching the terry lining with pins and sewing it. The easiest step was decorating the potholder. The hardest thing was overlocking the denim pieces.

Figure 1. Example of third grade pupil's photo and text in her ePortfolio.

Figure 2. Example of third grade pupil's photo and text in his ePortfolio.

Finnish municipalities and schools take independent care of the pedagogic goal-setting related to ICT learning and teaching. I had to define and set goals for the digital documentation of the work processes, taking pupils' ages and skill levels into account. The following goals acted as a starting point for the ePortfolio creation.

> *Gain a basic understanding of Peda.net service and ePortfolios.*
> *Gain basic desktop and tablet computer skills (log in/log out, navigating, text-writing and editing).*
> *Learn the process of ePortfolio creation, and rules for process reporting (take a photo, save the photo on Peda.net, add a caption and write textual content).*
> *Learn together and develop collaboration skills.*

(1)

I used the results of a pre-questionnaire on pupils' prior ICT experiences in planning the actual project. Both desktop and tablet computers (Apple iPads) were used in the ePortfolio creation.

Methodology and research design

The study followed an autoethnographic approach in the context of ethnographic fieldwork and writing. The approach was used in contexts familiar to me and included participant observation (Angrosino, 2012; Atkinson & Hammersley, 1994; Van Maanen, 1995), due to the fact that I, in the role of teacher and researcher, was involved as a member of the social setting under examination. I use a fictive name of the school and pseudonyms to protect the anonymity of the participants. The study was based on a data-producing process over a period of eight months in the 2016–2017 school year. The study can be regarded as a case study, a form of qualitative descriptive research, looking at a limited selection of participants (see for example Becker et al. 2012). Thus, no general conclusions can be drawn based on this study.

Various methodological strategies of autoethnography have been developed, and autoethnography is surrounded by polarised methodological debates. Approaches range from evocative self-exposure, with little abstraction or connection to theory, to analytical and realist description, with little focus on personal perspective (Holman Jones et al., 2013; Stahlke Wall, 2016). My intention was to conduct a study that lies between the evocative and the analytic approaches, also called 'moderate autoethnography' by Stahlke Wall (2016). Stahlke Wall (2016, p. 8) suggests that 'a moderate autoethnography would […] combine the power of the personal perspective with the value of analysis and theory, so that understanding is advanced in ways it might never have otherwise been'. In this study, my personal experience of ICT

barriers is connected with the broader social context in themes that I explain and elaborate in detail, both systematically and analytically, based on Ertmer's (1999) conceptual framework.

Data producing

Observation is at the core of ethnographic fieldwork, as recorded in field notes. I began producing data in September 2016 by taking field notes about the first phases of the ePortfolio project, which involved informing the pupils, parents and other teachers, setting up the learning environment and accompanying the pupils to the computer lab. While teaching and observing our lessons and having discussions with other teachers, I paid special attention to occurrences which could be interpreted as obstacles to the use of ICT in class, as well as to interactions that touched ICT barriers. Field notes and the research journal were kept for eight months, until the end of the project in May 2017. The validity of the research data was strengthened by supplementing the research journal data with audio-visual recordings using a digital camcorder. I recorded my own class, both in the computer lab (4 lessons) and in our own classroom (2 lessons) during the ePortfolio project. In addition to discussion with the teachers throughout the school year, I interviewed Lisa and Tina with a voice recorder at the end of the project in order to study their opinions on the project. Transcribing the complete record was conducted by me rather than by external transcribers.

Data analysis

As the ePortfolio project evolved, I began analysing my field notes and video recordings. The ongoing analysis of my raw data guided me towards questions and topics which I wanted to discuss with Lisa and other teachers to obtain participant perspectives on the events and processes. I conducted a qualitative thematic analysis on the data by following the six steps prescribed by Braun and Clarke (2006): 1) Familiarising with data, 2) Generating initial codes, 3) Searching for themes, 4) Reviewing themes, 5) Defining and naming themes, and 6) Producing the report. Thematic analysis is described as 'a method for identifying, analysing and reporting patterns (themes) within data' (Braun & Clarke 2006, p. 79). I used the Atlas.ti program, a computer program that can be utilised in qualitative data analysis (see for example Fielding 2001), in conducting the thematic analysis steps 2-5. The steps were not conducted in a rigid sequence, but in a recursive or cyclical way.

In data analysis, I focused on the findings which reflected barriers impeding ICT integration in the ePortfolio project. I used the conceptual framework of Ertmer (1999) as a tool for positioning intrinsic or extrinsic factors as possible causes of ICT barriers. The ICT barriers were examined at micro-level in the classroom context (cf. Jerolmack & Khan, 2017). The starting point of the study was the micro-level in the form of interactions and occurrences recorded in the field notes, research journal and digital recordings. In thematic analysis, these micro-level interactions and occurrences were grouped to form the themes, that is, the five main categories of the ICT barriers, that are considered the macro-level barriers in this study.

Every micro-level barrier was thus labelled an internal or external ICT barrier based on Ertmer's framework. I subsequently grouped the micro-level barriers, i.e. classroom occurrences or teacher opinions, into tentative macro-level categories. I compared every newly identified micro-level barrier to the existing macro-level categories and either added it into that category, created a new tentative category or recoded an already existing category to account for its

micro-level barriers as the properties and definitions of that particular category developed further. I continued data analysis until the tentative categories were saturated, additional data fit into the existing categorisation and no more recoding of micro-level occurrences or macro-level categories of barriers was needed. In other words, the trustworthiness of the data analysis method was strengthened by reaching theoretical saturation before defining the final macro-level categories.

Self-reflexivity

I played the multi-faceted role of researcher, informant, teacher, ICT mentor and author. My role amongst other teachers was that of a colleague rather than an outsider. However, there were certain aspects in doing fieldwork in my own practice I had to be aware of. I needed to pay special attention to the fact that I, firstly, did not try to control everything excessively but rather let things happen, and secondly, took notes on the developments from the viewpoint of a researcher, without neglecting details already familiar to me. In autoethnography, the author's voice is de facto heard, but in my research, both formal and informal discussions with teachers under investigation enabled me to develop a shared social identity with my colleagues, and the findings of the study, to a certain extent, developed into collective findings. I intertwined my experiences with the views of other teachers in order to indicate the sharing of experience among multiple subjects (Chang, 2008; Ellis et al., 2011).

Findings: external and internal barriers

In the following, my intention is to illustrate the main themes which the qualitative analysis of my research data revealed. As a result of the analysis, I identified five main categories of ICT barriers in our ePortfolio project, macro-level barriers which are summarised in Table 1 and are handled separately and presented with supporting quotes in the text. The first four categories represent external barriers, which may generally be eliminated by securing sufficient resourcing (Ertmer 1999). The fifth category, teacher attributes, has to do mainly with teachers' beliefs and attitudes and represents deeply internal barriers (cf. Ertmer, 1999). I use quotes that I recorded during the ePortfolio project to demonstrate how macro-level barriers manifest at the micro-level in classroom action. The quotes emerge from the self-reflexive field journal and from the transcripts of the video and audio recordings. It is always mentioned whose voice is being heard in the quotes.

Table 1. ICT barriers classification based on qualitative data analysis.

Classification category (macro-level barrier)	**Definition (sub-category of macro-level barrier)**	**Examples (How macro-level barriers manifest at micro-level? Ex = Example)**
A) Inadequate software/hardware	A1 Poor usability of Peda.net for ePortfolio purposes	A1Ex1 Saving a photo and adding some text required more than 20 steps in the user interface of Peda.net A1Ex2 Logic and user interface components of Peda.net were not optimal for ePortfolios
	A2 Complicated login procedure with desktop computers	A2Ex1 Multiple logins, and several usernames and passwords were needed A3Ex1 Some pupils' user accounts in school network were locked

	A3 Unpredictable occurrences	A3Ex2 Access to broadband or wireless network was unstable
B) Learner group attributes	B1 Young pupils' lacking abilities in ICT skills	B1Ex1 Computer login/logout difficulties appeared (see also A2 above) B1Ex2 Text input problems occurred B1Ex3 Accidental deletion of content by pupils happened B1Ex4 Extra preparatory work for the teacher was needed due to pupils' lack of skills
	B2 Large class size and heterogeneous group of pupils	B2Ex1 Chaotic learning situation B2Ex2 Providing sufficient level of support was not possible
C) Allocation of responsibility	C1 Often class teacher does not act as a crafts teacher	C1Ex1 Multidisciplinary approach was difficult, because there was no flexibility in teaching hours
	C2 Parents' role in enabling learning environment usage	C2Ex1 Delays by parents in creating user accounts affected project schedules C2Ex2 Usernames and passwords created by parents were too complicated C2Ex3 Some user accounts created by parents did not work
D) Lack of resources	D1 Lack of time available in the curriculum	D1Ex1 Crafts teachers' unwillingness to do ePortfolios with pupils due to lack of time D1Ex2 Documentation had to be organised partly beyond crafts teaching hours D1Ex3 Project progress was slow
	D2 Lack of education assistants	D2Ex1 = B2Ex1 D2Ex2 = B2Ex2
	D3 Lack of equipment	D3Ex1 Computer lab was rarely available
E) Teacher attributes	E1 Lack in teachers' ICT skills	E1Ex1 Impossible to even start the project without tutor/teacher help due to technical challenges related to Peda.net service
	E2 Teachers' attitudes	E2Ex1 Extra effort was required from the teacher

Inadequate software/hardware

According to Yuksel et al. (2013), lack of hardware and limitations of the hardware are the most significant barriers to effective ICT integration in the primary school context. However, barriers related to inadequate software are more numerous in my data than hardware-related barriers. This reflects the unsuitability of the Peda.net service for our specific needs related to craft documentation with young pupils. The Peda.net service features various user interface elements and components which can be used when creating and disseminating digital content such as pages, text modules and image modules. There was no ready ePortfolio structure available from the service, so I had to design and construct one to be used by the pupils. Setting up the system, creating ePortfolio templates in the personal spaces of the pupils and adjusting the settings accordingly was laborious and time-consuming, as is visible in the following quote

from the field journal.

> *From the beginning of September, I have been creating portfolio pages in pupils' personal spaces and changed the default settings so that I, as a teacher, am able to view every portfolio. I had to collect every pupil's username and password for this operation. It would make sense to let older pupils follow the procedure themselves, but for third graders the procedure is simply too complicated.*
> *(Field journal, 26.9.2016)*

Thus, the initial phase of the project took longer than expected, and I had to provide a great deal of support for Lisa and Tina in technical matters, as they were setting up the ePortfolio system for their classes. My class saved the first photos of their crafts artefacts on Peda.net in mid-October, Lisa's class at the end of January and Tina's class only at the end of March. The implications of the inappropriate software became apparent during the first months of the project in the form of, among other things, overtime work (lines 1–3) and Tina's demotivation (lines 6–8).

> *L1 We have been working for several weeks with Lisa (mainly during breaks and after school*
> *L2 days) in order to get the Peda.net user accounts finalised and portfolio blanks created in pupils'*
> *L3 personal space and linked to Lisa's personal space. […] Cathy and I (another ICT mentor*
> *L4 teacher in our school) organised three one-and-a-half-hour Peda.net workshops for teachers in*
> *L5 December. Lisa was able to join these workshops for a couple of hours, and we were finally*
> *L6 able to finish the preparatory activities for Lisa's class. Tina felt that the procedure should be*
> *L7 handled by crafts teachers, not by her. Cathy and I promised to provide support for Tina. She*
> *L8 managed to create portfolio pages for ten pupils today.*
> *(Field journal 15.12.2016)*

Taking photos of crafts artefacts with the iPads was simple, but the procedure for navigating Peda.net, creating and naming a new page for the photo in the pupil's ePortfolio and saving the photo there required over 20 clicks. I wrote a step-by-step guide to be used when adding new content in the ePortfolio. Despite the instructions, the pupils needed an adult to help with the procedure. This complexity of the tool was a surprise to me. It became clear that for our specific needs, Peda.net was not optimal. Proper testing or a pilot round would have revealed this fundamental problem of the tool for our purposes. The extra adults played an important role in the success in our project, as is visible in the following quote.

> *Lisa's class started crafts photographing the day before yesterday. Crafts lessons are so hectic that without extra adults, there is little opportunity to take the photos and save them in Peda.net. Alex, a student in vocational ICT programming getting acquainted with working life in Owl School, took one pupil at a time out of the classroom to take a photo of their crafts artefact to save the photo in Peda.net.*
> *(Field journal 1.2.2017)*

Using Peda.net on desktop computers required multiple logins by the pupils. The pupils had to log in to the desktop computer, to the school network and finally to the actual Peda.net service. There were separate usernames and passwords to be used for these separate login procedures. Login-related problems, depending on the perspective, are categorised in Table 1 under 'Inadequate software/hardware' (desktop procedure), under 'Learner group attributes' (young

pupils with inabilities) or under 'Allocation of responsibility' (parents created overly complicated user accounts).

We also encountered unpredictable ICT-related issues, not related to Peda.net, during the ePortfolio project. Such occurrences require immediate actions from the teachers, and re-planning is often needed. One time, when the Owl School network went down, for instance, we had to cancel the crafts photographing with Lisa's pupils.

Learner group attributes

Digital technology use in schools often manifests as a more compromised reality than expected. Selwyn (2011, p. 25) refers to the 'messy realities of digital technology use in 21st century school systems' and argues (Selwyn 2011, p. 58) that the use is 'less extensive and sophisticated than it could be'. Based on the pre-questionnaires on the pupils' prior ICT experiences, every pupil had previously used both a tablet computer and a desktop computer, mainly for playing games and watching YouTube videos, but in our project, the skills needed were different. When young pupils are involved, clearly defined sub-goals for the pupils are needed in order to meet the requirements of truly integrating ICT into pedagogy. As stated earlier, the NCC (2016) does not define such goals. Large class sizes and heterogeneity in relation to pupil ICT skills may become a barrier for the teacher if the teacher does not have the tools, or even the confidence, to handle the complex situation. 'Learner group attributes' is a macro-level barrier which is not taken into account in the ICT literature, and I consider it primary-school-specific.

Most of the pupils did not remember their usernames or passwords, even at the end of the project. I documented pupils' login credentials on papers which I gave them every time they were supposed to work on their ePortfolios, and I collected the papers when the lesson was over. Logging into the desktop computers was laborious, due to the multiple logins explained in the previous chapter. The following quote is one of the most significant in the study in relation to the messy realities of primary school digitalisation. It shows us concretely the starting point of digitalisation with young pupils. There were lessons when some of the pupils had to log out immediately after logging in, as the lesson was already over.

> *Login to the computers by pupils took an eternity, even though there were only ten pupils in the computer lab with me. It took about 20 minutes in total for the login procedure, which consisted of logging into the Owl School network and logging in to the Peda.net service. The pupils did not recognise the typos they made when typing their usernames and passwords (for example, extra spaces or missing letters), and there were pupils who were simply not able to type a long username at all.*
> *(Field journal 18.1.2017)*

The logout procedure was also difficult. In the late phases of the project, there were still pupils who simply pressed the power button of the computer to log out. Switching to edit mode and saving the created content were also difficult procedures to remember. Text-input-related problems occurred frequently. All in all, virtual keyboard usage was more familiar to, and easier for, the pupils than desktop keyboard usage, such as for entering special characters. Skill heterogeneity among pupils was a fact, as is visible in the two following quotes. In the first example, Ann has already written her text, whereas some of the pupils are not even able to

switch to the edit mode (lines 4–6). In the second example, Lisa described skills varied among pupils (lines 7–11).

> *L1 Teacher: Let's check those difficult signs now. It is quite easy to enter the @ sign with a tablet*
> *L2 computer, because it is available in the virtual keyboard. You don't need to enter it as a key*
> *L3 combination like with the desktop computer.*
> *L4 Ann: My text is ready. (Ann gives her iPad to the teacher).*
> *L5 Teacher: (Teacher goes to the back of the class. There are still pupils that are not able to switch*
> *L6 to the edit mode.) Just press here in order to activate the edit mode.*
> *(Video recording in our own classroom, iPads being used 10.5.2017)*

> *L7 Lisa: The skills of the children varied a lot. Some were able to do things, everything was easy*
> *L8 for them, and they progressed smoothly in writing ePortfolio descriptions. Then there were*
> *L9 pupils who couldn't get anything done and needed an adult to sit next to them for almost the*
> *L10 entire lesson. But overall, this phase of the project went pretty well, because we were allowed*
> *L11 to conduct simultaneous teaching, and we were monitoring the computer lab together.*
> *(Lisa and Tina's interview 24.5.2017)*

All in all, the lessons in the computer lab were chaotic. The pupils were often impatient and walked about as they asked for help from the teachers or other pupils.

Allocation of responsibility

The macro-level barrier 'Allocation of responsibility' can be considered both primary-school-specific and crafts-specific. Previously, Konstantinos et al. (2013) have considered the lack of cooperation between ICT teachers and teachers of other school subjects at the primary school level as a barrier. In this study, this aspect is seen more broadly, as the cooperation happened between class teachers and crafts teachers, as well as school assistants and parents.

There are two hours of crafts teaching per week in the third graders' curriculum (NCC, 2016). Often, the class teacher does not act as a crafts teacher, and another teacher takes care of the crafts lessons. According to my experiences, creating ePortfolios is not easy if the class teacher and the crafts teacher are not the same person. First, there is no flexibility in teaching hours from the crafts teacher's point of view. Second, the crafts teacher may not be willing to waste too much of the weekly two-hour quota for documentation activities. If the class teacher acts as a crafts teacher for his or her class, there is more flexibility, because the teacher may quite easily rearrange the weekly timetable. The macro-level barrier 'Lack of resources' is thus connected to the macro-level barrier 'Allocation of responsibility', as limited time has an impact on the crafts teachers' willingness to cooperate and take responsibility in digital documentation. In our ePortfolio project, I tried to organise an extra adult, such as a school assistant, to take care of the photographing of the crafts artefacts with the pupils. If that was not possible, we brought the ready crafts artefacts into our own classroom, and I helped the pupils to take the photos during breaks. Lack of time to conduct the documentation was a problem from crafts teachers' point of view as is visible in the following two quotes.

> *Cathy, one of the crafts teachers, said that she was not able to handle the crafts photographing with the pupils during crafts lessons, as she was mainly alone with the pupils. I went to help her, as I had no lessons when she had crafts lessons. I took*

one pupil at a time out of the classroom to take a photo of their crafts artefact to save the photo in Peda.net.
(Field journal 15.2.2017)

I asked Sally, one of the crafts teachers, whether she had an idea, how she could handle the crafts photographing and ePortfolio writing with the pupils. She said that there is not enough time and that she cannot do that with the pupils during crafts lessons. We decided that I take the ready crafts artefacts with me and organise the photographing and writing when I have time. According to Sally it is really strange that no extra hours are allocated to crafts teaching even though there is now the requirement to do digital documentation with the pupils.
(Field journal 22.2.2017)

The fact that the parents needed to give their permission by creating the Peda.net user accounts for their children heavily affected our project's schedule. The parents were instructed in the process, but when dozens of parents are involved, there are sure to be problems and misunderstandings. There were delays by some parents in providing the user accounts for the pupils (lines 5–6). Lisa, Tina and I had to send friendly reminders to the parents to finish this task. Some parents wanted us teachers to create the user accounts for their children (Lines 1–2). Additionally, some of the usernames and passwords created by the parents were far too complicated for a third grader to type in.

L1 Finally, every pupil in my class has a Peda.net username and password. I handled the two
L2 missing accounts myself, as the families asked me to do so. This procedure is totally fine, as
L3 stated in the Peda.net user account instructions. Additionally, there were two usernames that
L4 did not work, even though the parents had informed me that they had followed the instructions.
L5 I called the parents and found out that the problem was that the parents had not clicked the
L6 activating link sent to their email addresses.
(Field journal 31.10.2016)

Lack of resources

In the literature, ICT barriers related to a lack of resources refer mainly to lack of technology, lack of access to available technology, lack of technical support and lack of time (BECTA 2004; Hew & Brush, 2006; Yuksel et al., 2013). According to Hew and Brush (2006), resource barriers are the most frequently mentioned technology barriers in the literature. In this study, the lack of technology manifested in the fact that there was only one computer lab, with 25 computers, in Owl School for 800 pupils in the school year 2016–2017, and there were no laptops for pupils available yet. On the other hand, tablet computers (i.e. iPads) were more readily available. Additionally, the computer lab reservation tool was unreliable, and it was often difficult to find a free slot in the reservation calendar.

Lisa: There were all the practical issues that did not work, like reserving computer lab slots by means of the reservation tool. There were double reservations, even though you thought you managed to reserve some time for your class. Once we were in the lab with a group of upper-comprehensive school pupils at the same time (laughs). In my opinion, there should be more computers available for the small pupils.

(Lisa and Tina’s interview 24.5.2017)

The lack of pupil ICT skills (see also ‘Learner group attributes’) and lack of school assistants or extra adults impeded educational technology integration in this study. Going with 20–25 young pupils into the computer lab at the same time is laborious. An extra adult is needed to get things done. For example, Cathy and Sally, crafts teachers, said that they were not able to handle the crafts photographing or ePortfolio writing with the pupils during crafts lessons, as they were mainly alone with the pupils (see the quotes in section ‘Allocation of responsibility’).

Teacher attributes

The study of Yuksel et al. (2013) conducted in Turkey shows that young teachers’ self-confidence in terms of ICT skills is stronger than self-confidence of teachers with more years of teaching experience. It was not possible to verify this in my autoethnographic study. In this study, internal barriers were rare and all belong to the same macro-level category ‘Teacher attributes’. My role as an ICT mentor was emphasised during the project and certainly affected the fact that the external findings are emphasised. This can be explained by the insider-research nature of my study. I, as an ICT mentor teacher, am confident in my own ICT skills and have a great deal of experience with pedagogic software usage. I gave support to other teachers in technical matters during the project. Internal barriers in this study emerge from the interview and discussion data. Both Lisa and Tina reflected on their insufficient knowledge of the Peda.net service and highlighted the fact that the researcher–teacher’s support, especially in the early phases of the project, was crucial. The following two quotes stem from the interview I organised with Lisa and Tina at the end of the project. Lisa and Tina point out the importance of professional teacher development possibilities in gaining comprehensive knowledge of ICT tools and resources. Both regard their ICT skills as insufficient to start a project such as this by themselves, without any support.

> *Lisa: The Peda.net school network was totally new to me, and I found it a bit difficult and complicated in the beginning. I think the expertise and support provided by the researcher–teacher was important. The first phases of the project were laborious, but the support provided was so meaningful that we were able to start the project and the pupils got excited to do it.*
>
> *Tina: I agree with Lisa that the support by the researcher–teacher was crucial. Without it, I would not have been able to get started in the project. Also crucial was the Peda.net hands-on training for teachers. But a lot of extra time was needed, and I had the feeling that more training at the very least would be needed to gain knowledge in ICT skills.*
> *(Lisa and Tina’s interview 24.5.2017)*

Conclusion and discussion

In this autoethnographic study I have combined the aspects of ICT and craft education at primary level. The study aimed in share the challenging experiences of teachers involved in the implementation of technology in primary craft education as the pupils were to document their crafts processes in ePortfolios. ePortfolio has shown to be a workable method in craft

education (Saarinen et al. 2016), and it fulfils the curriculum requirements of digital documentation in crafts in basic education (NCC, 2016). However, mainly due to the inappropriate tool, the findings of this study revealed the messy realities of digital technology use in a Finnish primary school craft education, which were categorised and analysed by means of qualitative thematic analysis (Braun & Clarke, 2006) and Ertmer's (1999) conceptual framework on 'first- and second-order ICT barriers'. As a result, I have reported five main categories of barriers to ICT integration, which are 'Inadequate software/hardware', 'Learner group attributes', 'Allocation of responsibility', 'Lack of resources' and 'Teacher attributes'. These findings concerning digital documentation in crafts align with the generic primary school ICT barrier literature (e.g. Konstantinos et al.' 2013; Vanderlinde et al., 2015; Yuksel et al., 2013). However, the generic literature does not take into account the young pupils' lack of ICT skills or the role of parents and other adults in the learning processes, which, based on my findings, are fundamental at primary level, as shown in the present ePortfolio project in crafts documentation. In this study, these two aspects are included in primary-school-specific macro-level barriers that I call 'Learner group attributes' and 'Allocation of responsibility'. Furthermore, the macro-level barriers 'Allocation of responsibility' and 'Lack of resources' are firmly connected to the school subject crafts due to inflexibility in teaching hours, when class teacher does not act as a crafts teacher, and due to limited time available in the crafts curriculum to conduct digital documentation. When ePortfolios are introduced, some of the barriers reported in this study may arise regardless of school subject, some are more specifically related to craft education, but it is to be noted that as a whole, the findings of this study have arisen from the context of craft and technology education in Finnish primary level. Thus, the findings reflect the aspects of that particular school reality with its objectives, contents and structures. Furthermore, since the study is based on a limited selection of participants, no general conclusions can be drawn.

In terms of the NCC (2016), the documentation of one's own work processes in craft education is connected not only to ICT but also to multiliteracies as a transversal competence (NCC 2016; Saarinen et al., 2016). In the present ePortfolio project the pupils were to, for instance, take photos of their crafts artefacts and to describe the making of them, which required multimodal textual skills. Thus, ePortfolios as a form of documenting crafts processes support not only the understanding of design and crafts processes but also the development of these transversal skills as a part of craft education. However, as this study shows, the lack of ICT skills of young pupils and the role of parents and extra adults should be more specifically taken into account when planning the ePortfolio lessons in order to get the full potential of the ePortfolio method as an educational tool. This is connected not only to lack of time but also to teachers' possibilities and willingness to organise their teaching concerning crafts documentation. Based on the results, the learning of very basic ICT skills, such as logging into the school network and the Peda.net service, took a lot of time and less attention was paid on further formulation of ePortfolio content itself.

The notion in the literature that teachers' agency in influencing technology adoption in schools is often limited (Selwyn, 2011) applies to our experience. It became evident that the Peda.net environment was not optimal for our specific ePortfolio needs with young pupils. In our project, neither the teachers nor the school administrators had the technical expertise or understanding of the digital tool used. It is to be noted that this does not mean that the tool would not work

for other purposes. Thus, in planning ePorfolio lessons in crafts, it is essential that the teachers involved have understanding of the digital tools, and agency in choosing the appropriate digital tools.

The Finnish NCC (2016) obligates extensive use of digital technology in schools. However, this study revealed a contradiction between this policy and the reality teachers face in schools. It remains largely open in *what* and *how* to integrate technology, as the pedagogic goals are defined on a very general level. On one hand, the NCC (2016) offers high levels of autonomy to Finnish teachers in ICT integration, which can be regarded as a positive point. On the other hand, the fact that technology goals remain vague can easily lead to inequity among pupils, as the implementation may vary considerably between Finnish municipalities, schools and teachers.

The autoethnographic nature of my study made it possible to include details based on lived experiences, which deepened the understanding of the ICT barriers at primary level. Ertmer's framework (Ertmer, 1999) worked as a profoundly useful tool in classifying ICT barriers encountered throughout the study. However, it should be noticed that the classification is always dependent on researcher's interpretation and that some of the categories in the findings of this study overlap.

To my knowledge, this is the first study providing empirical evidence on barriers restricting the use of ICT within the youngest age groups in primary craft education. It shows the challenges in incorporating the aspects of transversal skills such as ICT and multiliteracies (NCC, 2016) into subject specific craft education. However, by outlining the basic ICT learning goals in detail and by providing the teacher agency in adopting ICT tools, it is possible to support the planning of future ePortfolio projects in craft education. Future research should continue exploring the use of ePortfolio as method by taking into account various ICT tools in different age groups in craft education.

References

Admiraal, W., Louws, M., Lockhorst, D., Paas, T., Buynsters, M., Cviko, A., Janssen, C., de Jonge, M., Nouwens, S., Post, L., van der Ven, F., and Kester, L. 2017. Teachers in School-Based Technology Innovations: A Typology of their Beliefs on Teaching and Technology. *Computers & Education* 114: 57–68. doi: 10.1016/j.compedu.2017.06.013

Angrosino, M.V. 2012. Observation-based Research. In J. Arthur, M. Waring, R. Coe, L.V. Hedges (eds.), *Research Methods & Methodologies in Education*, 165–169. London: Sage.

Atkinson, P. & Hammersley, M. 1994. Ethnography and Participant Observation. In N.K. Denzin, and Y.S. Lincoln (eds.), *Handbook of Qualitative Research*, 248–261. Thousand Oaks: Sage.

Barrett, H. 2010. Balancing the two faces of ePortfolios. *Educação, Formação & Tecnologias-ISSN 1646-933X,* 3(1), pp. 6-14.

Becker, B., Dawson,P., Devine,K., Hannum, C., Hill,S., Leydens,J., Matuskevich, D., Traver,C., and Palmquist, M. 2012. Case Studies. Writing@CSU. Colorado State University. https://writing.colostate.edu/guides/guide.cfm?guideid=60.

Blau, I. & Shamir-Inbal, T. 2017. Digital Competences and Long-Term ICT Integration in School

Culture: The Perspective of Elementary School Leaders. *Education and Information Technologies* 22, no. 3: 769–787. doi: 10.1007/s10639-015-9456-7
BECTA 2004. British Educational Communications and Technology Agency 2004. A Review of the Research Literature on Barriers to the Uptake of ICT by Teachers. http://dera.ioe.ac.uk/1603/1/becta_2004_barrierstouptake_litrev.pdf
Braun, V. & Clarke, V. 2006. Using thematic analysis in psychology. *Qualitative Research in Psychology.* (3)2: 77-101. doi: 10.1191/1478088706qp063oa
Chang, H. 2008. *Autoethnography as Method*. Walnut Creek, CA: Left Coast Press.
Cope, B. & Kalantzis, M. 2009. “Multiliteracies”: New literacies, New learning. *Pedagogies: An International Journal.* (4)3. DOI: 10.1080/15544800903076044
Dix, A., Finlay, J., Abowd, G.D., and Beale, R. 2004. *Human-Computer Interaction.* Third edition. Pearson Education Limited.
Ellis, C., Adams, T.E., and Bochner, A.P. 2011. Autoethnography: An Overview [40 paragraphs]. *Forum Qualitative Sozialforschung / Forum: Qualitative Social Research*, 12, no. 1, Art. 10. http://nbn-resolving.de/urn:nbn:de:0114-fqs1101108
Ertmer, P. 1999. Addressing First- and Second-Order Barriers to Change: Strategies for Technology Integration. *Educational Technology Research and Development*, 47, no. 4: 47–61. doi: 10.1007/BF02299597
European Commission 2013. Survey of Schools: ICT in Education. Benchmarking Access, Use and Attitudes to Technology in Europe’s Schools. Final Study Report. doi: 10.2759/94499
Fielding, N. 2001. Computer Applications in Qualitative Research. In P. Atkinson, A. Coffey, S. Delamont, J. Lofland, and L. Lofland (eds.), *Handbook of Ethnography*, 453–467. London: Sage.
Hew, K.F. & Brush, T. 2006. Integrating Technology into K–12 Teaching and Learning: Current Knowledge Gaps and Recommendations for Future Research. *Educational Technology Research and Development* 55, no. 3: 223–252. doi: 10.1007/s11423-006-9022-5
Hoikkala, T. & Kiilakoski, T. 2018. Digitalisaation pedagogiikka ja jatkuvan oppimisen ristiriidat [The Pedagogy of Digitalisation and the Contradictions of Continuous Learning]. In *Koulutuksen digiloikka – Miten onnistumme suomalaisten osaamisen päivittämisessä?* [The Digital Leap of Education. How Do We Succeed in the Updating of Finns’ Know-How?], 12–53. Helsinki: Teollisuuden palkansaajat TP. https://www.tpry.fi/edistys-julkaisusarja/edistys-raportit/koulutuksen-digiloikka.-miten-onnistumme-suomalaisten-osaamisen-paivittamisessa..html
Holman Jones, S., Adams, T.E., and Ellis, C. 2013. *Handbook of Autoethnography.* Walnut Creek, CA: Left Coast Press.
Jerolmack, C. & Khan, S. 2017. The Analytic Lenses of Ethnography. *Socius: Sociological Research for a Dynamic World* 3: 1–11. doi: 10.1177/2378023117735256
Kirschner, P.A. 2015. Do We Need Teachers as Designers of Technology Enhanced Learning? *Instructional Science* 43, no. 2: 309–322. doi: 10.1007/s11251-015-9346-9
Konstantinos, T., Andreas, A., and Karakiza, T. 2013. Views of ICT teachers about the introduction of ICT in primary education in Greece. *TOJET: The Turkish Online Journal of Educational Technology* 12, no. 1: 200–209.
Kress, G. 2003. *Literacy in the New Media Age*. London: Routledge.
Lorenzo, G. & Ittelson, J., 2005. An overview of e-portfolios. Educause learning initiative, 1, pp. 1-27.
Kuan-Cheng, L., Shu-Huey, Y., Hung, J.C. and Ding-Ming, W., 2006. Web-based appreciation and

peer-assessment for visual-art education. *International Journal of Distance Education Technologies,* 4(4), pp. 5.

NCC 2016. National Core Curriculum for Basic Education (2014). Finnish National Board of Education 2016: 5. E-book. Accessed Apple iBook.

New London Group 1996. A pedagogy of Multiliteracies: Designing Social Futures. *Harvard Educational Review*, 66, no 1: 60-93. https://doi.org/10.17763/haer.66.1.17370n67v22j160u

Nicolaidou, I. 2013. E-Portfolios Supporting Primary Students' Writing Performance and Peer Feedback. *Computers & Education* 68: 404–415. doi: 10.1016/j.compedu.2013.06.004

OECD 2012. Public and Private Schools: How Management and Funding Relate to their Socio-economic Profile. Paris: OECD Publishing. https://www.oecd-ilibrary.org/education/public-school-private-school_9789264175006-en

Saarinen, A., Seitamaa-Hakkarainen, P., and Hakkarainen, K. 2016. The Functions and Benefits of the ePortfolio in Craft Education at the Primary Level. *Design and Technology Education* 21, no. 3: 29–40. https://ojs.lboro.ac.uk/DATE/article/view/2156

Saarinen, A., Seitamaa-Hakkarainen, P., and Hakkarainen, K. 2019. Building Student-centric ePortfolios in Practice: Areas of Documentation in a Craft Learning Activity. *Techne Series: Research in Sloyd Education and Craft Science A, 26*(2), 16–28. https://journals.hioa.no/index.php/techneA/article/view/3261

Sefton-Green, J., Marsh, J., Erstad, O., and Flewitt, R. 2016. Establishing a Research Agenda for the Digital Literacy Practices of Young Children: A White Paper for COST Action IS1410. http://digilitey.eu

Selwyn, N. 2011. *Schools and Schooling in the Digital Age: A Critical Analysis*. New York, NY: Routledge.

Stahlke Wall, S. 2016. Toward a Moderate Autoethnography. *International Journal of Qualitative Methods* 15 (1): 1-9. doi: 10.1177/1609406916674966

Tanhua-Piiroinen, E., Kaarakainen, S.S., Kaarakainen, M.T., Viteli, J., Syvänen, A., and Kivinen, A. 2019. Comprehensive Schools in the Digital Age: Publications of the Government's Analysis, Assessment and Research activities 6/2019. http://urn.fi/URN:ISBN:978-952-287-634-8

Van Maanen, J. 1995. An end to Innocence: The Ethnography of Ethnography. In J. Van Maanen (ed.), *Representation in Ethnography*. London: Sage Publications.

Vanderline, R., Aesaert, K., and van Braak, J. 2015. Measuring ICT Use and Contributing Conditions in Primary Schools. *British Journal of Educational Technology* 46, no. 5: 1056-1063. doi: 10.1111/bjet.12282

Yuksel, G., Nuray, G., and Ozlem, B. 2013. Enablers and Barriers to the Use of ICT in Primary Schools in Turkey: A Comparative Study of 2005–2011. *Computers & Education* 68: 211–222. doi: 10.1016/j.compedu.2013.05.002

The Reciprocal Nature of Pedagogical and Technical Knowledge and Skill Development between Experts and Novices

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Abstract

This paper outlines the findings of a study focused on the impact an expert teacher's pedagogical and technical knowledge and skill may have on the pedagogical and technical development of pre-service technology education teachers. Specifically, this inquiry falls within the context of traditional wooden boat building in Newfoundland and Labrador, Canada. Understanding the relationship between an expert's knowledge and skill, and the development of a novice's knowledge and skill is vitally important for institutions charged with graduating technology education teachers. Exploring the impact of pre-service teachers' pedagogical and technical development was considered in relation to an expert teacher's pedagogical content knowledge, and the nuance between declarative and procedural knowledge within technological activity. Data were collected from semi-structured interviews, workshop session observations, and researcher/participant journal entries. The sample was purposeful as the participants were recruited from boat building workshops between 2017 and 2019 and the 2017-2018 technology education diploma program cohort from Memorial University. Thematic analysis was used to identify major themes within the data. A descriptive visual framework based on the data analysis was constructed to highlight the complexities of teaching and learning within the multifaceted setting of a technical activity. An analysis of the data indicates that fostering and maintaining reciprocal interpersonal relationships between experts, novices, and peers are critical for the development of pre-service teacher technical and pedagogical knowledge and skill.

Keywords

PCK, technical knowledge, skill development, pre-service education, technology education, expert, novice.

Research on technology education teachers' beliefs and practices has revealed that there is a difference in their understanding of the nature of content knowledge as compared to other subject area teachers (Doyle, Seery, and Gumaelius 2019). While teachers of science, social studies, and other well-established subjects may tend to focus on concepts and knowledge acquisition as the basis of their pedagogical practice, technology education teachers still tend to focus on technological activity with less emphasis on conceptual knowledge (Doyle et al. 2018; Jones, Buntting, and de Vries 2013; Williams and Lockley 2012). How teachers know and enact their practice has been described through various interpretations of pedagogical content

knowledge (PCK) for the last three decades. While PCK was framed as the intersection of a teacher's subject matter knowledge, pedagogical knowledge, and context knowledge that informed their practice (Shulman 1986), this concept has matured. Moving away from a generalized elucidation of canonical teaching practice, the idea of situating PCK within specific teachers' experiences has emerged (Doyle et al. 2019). This evolution of thought on PCK may have a direct effect on technology pre-service education. As de Miranda (2017) has suggested, individual technology education teachers have their own unique domain specific knowledge and any hope of transmitting this knowledge to pre-service teachers is probably a near impossible task. Rather, as pre-service technology researchers and educators there is an opportunity to generate and evaluate useful pedagogical practices for the conceptual strains of technology education.

The idea of informing technology education teacher educators was the primary motivation for this study. Within the complex and situated nature of a technical activity, this paper will discuss the findings of a research study focusing on the question of whether the impact an expert teacher's pedagogical knowledge and skill and their technical knowledge and skill may have on the pedagogical and technical skill development of pre-service technology education teachers. Specifically, this question will be framed within the context of traditional small wooden boat building in Newfoundland and Labrador, Canada.

Context

Wooden boat building was an essential part of surviving in Newfoundland and Labrador, Canada for centuries. While this knowledge was once common throughout coastal communities, the advent of new synthetic materials, processing methods, and the demise of the inshore fishery in the latter half of the twentieth century, have all taken a toll on this traditional knowledge and skill. With no ties from the past to connect to the present, or plans to reach into the future, wooden boat building in Newfoundland and Labrador, Canada may be lost. Shils (1981) noted traditions that survive the test of time are those that evolve and adapt to changing conditions. As such, the Wooden Boat Museum of Newfoundland and Labrador has a mandate to protect, collect, and disseminate knowledge about the provinces' collective cultural heritage concerning the building and use of wooden boats throughout the province. Of primary importance to this study is the museum's technical wooden boat building knowledge. For the past four years (2017-2020), the Faculty of Education of Memorial University and the Wooden Boat Museum of Newfoundland and Labrador have jointly offered winter boatbuilding workshops and courses facilitated by a local master boat builder and teacher. These workshops and courses have provided a rich authentic context as pre-service technology education teacher candidates have participated in the workshops and the subsequent research study.

Theoretical Background

Expertise

What does it mean to be an expert? It has been suggested that superior human performance is predominantly acquired through experience (Ericsson and Smith 1991). While the acquisition of expertise was once thought to be the product of mastering general domain independent skills, this theory has given way to the idea that "expertness lies more in an elaborated semantic memory than in a general reasoning process" (Chi, Glaser, and Farr 1988:xxxv). Context matters in developing human performance and expertise and while general reasoning processes may not be as key as once thought, continued experience in a domain is still an important consideration (Chi et al. 1988). In particular, the idea of developing expertise through a combination of interactional socialization (the idea that you can develop an awareness and expertise through social immersion) and an individual's development of contributory tacit knowledge through practice of an esoteric skill, have been proposed as a more holistic sociological perspective on expertise (Collins and Evans 2018). In studying how an experienced teacher's expertise and practice influences pre-service teacher pedagogical and technical development it is important to understand some of the general fundamental differences between expert and novice thought and action.

While multiple theories and frameworks have been utilized to study the difference between expert and novice performance, similar findings persist. Using the structure, behaviour, and function framework Hmelo-Silver and Pfeffer (2004) found that experts had a deeper understanding of the behaviour and function of complex systems in comparison to novices' fixation on superficial structural features. Dixon and Johnson (2011) found similar patterns of simplistic reductionism in novices versus expert engineers using a conceptual framework of metaphors, analogies, and propositions while working through design problems. Engineering students relied on heuristics or "rules of thumb" to reduce the cognitive load while experts moved quickly to proposing solutions based on their divergent experience. The ability of experts to identify common conceptual structures across disparate surface features of design problems can take years of substantial experience to develop and is a key characteristic of what it means to be classified as an expert (Dixon and Johnson 2011). In terms of teaching expertise, Auerbach et al. (2018) found that expert teachers have the ability to better identify and respond to student thinking while creating opportunities for generative work compared to their novice counterparts. In addition, Auerbach et al. (2018) also noted that their sample of expert teachers varied a great deal in their interpretations of what constituted important elements of teacher knowledge. In essence, the experts highlighted the importance of context, which did not necessarily match with previously held viewpoints about set stages of expert development.

Dreyfus and Dreyfus' (1980; 2004) seminal work on expert development heavily emphasised five key stages: novice, competence, proficiency, expertise and mastery. While this model still has value in a general sense, critics have since pointed out that in real life, expertise lies much more on a continuum for each individual that can overlap multiple stages of the Dreyfus model. Dall'Alba and Sandberg (2006) theorized that the embodied understanding of the domain of practice is also an important consideration for understanding expert development –it is not just the transfer of professional knowledge, it is an intimate understanding of the professional practice as well. This idea about an embodied experience was reflected in the work of Collins and Evans (2018) earlier as they outlined fundamental underlying sociological aspects of developing expertise, both individually and in groups. Expertise is not something that can be achieved independently of the contextual and social boundaries of the domain in question. While these studies and theoretical works outline the importance of continued and sustained experience within an area of expertise, there should be an awareness that individual preferences and interests along with motivation and practice counters the idea that anyone can achieve expertise in any domain with just practice alone (Chi et al. 1988). In becoming an expert technology education teacher there should be an acknowledgment of the potential relationship between interest, motivation, practice, and experience within the technical and pedagogical realms.

Technical Knowledge and Skill

Subject matter knowledge or content knowledge in technology education can be conceptually problematic for novice teachers as it encompasses not only declarative knowledge, but also procedural knowledge. In its broadest sense, technology is a normative practice (Jones et al. 2013) with practitioners relying on both an understanding of declarative and procedural knowledge –what Ryle (1949) originally described as the difference between "knowing that" and "knowing how" (p. 28-29). While this may sound like an easy way to compartmentalize different types of knowledge, modern psychological theories point to a much more unified and dynamic view (Haye and Torres-Sahli 2017).

The relationship between cognitive (declarative) and tacit (procedural) technical knowledge was difficult to analyze before the professionalization of technological communities as this knowledge was generally diffused through master apprentice interactions (Laudan 1984). While much work has been done to capture procedural knowledge related to actively participating in particular technological activities, these attempts typically do not convey the nuance of knowing how to execute a skill. More importantly they do not capture how to execute a skill well –the act of doing technology is essentially a form of living knowledge that is critical for any given material tradition. As de Vries (2016) has mentioned "textbooks are no option for teaching and learning knowledge that cannot be adequately expressed in propositions" (p. 37). Therefore, the act of learning through doing is important for developing proficiency in understanding both knowledge and skill, as Eraut (2004) pointed out, tacit knowledge is not only the implicit acquisition of knowledge, but also the implicit processing of knowledge. Haye and Torres-Sahli (2017) theorize that we are unable to separate forms of

knowledge, they do this by analyzing current theory in relation to William James' conceptualization of mind being a relationship between body, affective feeling, and temporal experience. In essence, knowledge is practical thinking. The mind is ever changing and the stream of consciousness it produces can be captured in a facsimile that has been represented as declarative knowledge. Therefore, Haye and Torres-Sahli (2017), stated that declarative knowledge is not independent and that a holistic understanding of knowledge can be viewed as "… a changing process rooted in bodily dynamics and history" (p. 53). This stream of thought or knowledge has to have a context –we are always thinking of something. For technology educationalists, artifacts are typically that something.

Is a technological artifact a type of knowledge, or is it merely the end state and a representative form of other types of knowledge? As discussed above, the distinction between a dualistic notion and separation of declarative and procedural knowledge is currently not as strong as it once was. While technology can be viewed through multiple lens, Mitcham's (1994) four modalities of knowledge, process, artifact, and volition are used extensively in technology education as a basic foundation (de Vries 2016). This connection between Mitcham's modalities highlight that an artifact is imbued with more than its physical characteristics, an idea that Baird (2004) took even further. Baird (2004) asserted that scientific instruments are material objective knowledge –that instruments (technical artifacts) hold their own knowledge independent of subjective justified true belief. This he holds true through the demonstration of various instruments that worked consistently and reliably but were based on wrong or disproven scientific theory. Therefore, instruments more than encapsulate knowledge, they are a form of knowledge in and of themselves. This idea has been found to be problematic from the perspective of traditional schools of thought on the nature of knowledge. As Kletzl (2014) pointed out, Baird's theses did not account for a distinction between scientific and engineering theory, in which the procedural knowledge needed to manufacture working artifacts can be independent of each other. Kletzl (2014) maintained a traditional view of knowledge as justified true belief and that while an instrument can encapsulate knowledge, it cannot be knowledge.

The multiple positions concerning the relationship between declarative, procedural, and artifact knowledge within the context of technological activity forms a continuum of thought and action, reaction and evaluation, and further action. Wrestling with these ideas is essential for pre-service technology education teachers as they begin to develop their own pedagogical and technical skill within this curricular area.

PCK and PCK&S

As mentioned earlier, PCK has now been theorized to be more than the collective teaching practice of a specific domain. The idea that there are multiple layers between canonical and individual PCK has allowed researchers to propose more nuanced methods for investigating PCK generally, and specifically within technology education (Doyle et al. 2018; Gess-Newsome 2015; de Miranda 2017). One such idea is pedagogical content knowledge & skills (PCK&S). While

proposed for science education, the implications of this idea have value in technology education as well.

Gess-Newsome (2015) defined PCK as personal knowledge that teachers use to design and reflect on instruction. More specifically "PCK is context specific including the teaching of a particular topic in a particular way for a particular purpose to particular students" (Gess-Newsome 2015, p. 36). This idea can be related to the context and domain specificity of the development of expertise –that expertise, in this case teaching expertise, is context bound. Gess-Newsome (2015) also defined PCK&S as the "act of teaching" (p. 36) and this differentiates between what a teacher knows ("knowing that") and what they are able to do ("knowing how"). PCK&S is the embodiment of PCK within context. As such, it is the dynamic enactment of a teacher's ability to implement instruction, monitor student activity, and adjust their action based on in situ feedback from the context. While Gess-Newsome (2015) acknowledged that PCK&S is an elusive research subject to study due to its tacit nature, it is also one way to describe PCK in the context of an active classroom. These ideas were supported by a later study which confirmed the complex nature of trying to understand the relationship between teacher PCK and student achievement (Gess-Newsome et al. 2019). After working with 35 secondary teachers in a two year intervention focusing on developing stronger pedagogical and content knowledge in biology, Gess-Newsome et al. (2019) concluded that pedagogical knowledge was "… intertwined with the context of teaching specific students" (p. 961). It was also noted that while teachers in the study may have known how they wanted to teach, they may not have had the skill to achieve their goals. While this study illustrates the difficulty in capturing PCK in action for experienced teachers, novice teachers have similar experiences.

In evaluating preparedness to teach technology education Ramaligela (2020) used a 9E instructional model to analyze five pre-service teachers' content and instructional knowledge during their practicums in South Africa. Categories of *elicit, elaborate, explain, explore,* and *enclose* were used to evaluate technology content knowledge (TCK), while *enlighten, engage, exchange,* and *evaluate* were used to evaluate technology instructional knowledge (TIK) during single classroom observations of the five teachers. While the length of individual observations could be problematic in determining a representative sample of the pre-service teachers' instruction, nevertheless, Ramaligela (2020) reported that there was a wide variety in the pre-service teachers' ability to meet the criteria set forth by the 9E instructional model. The findings of this study indicated that this particular group of pre-service teachers did not have the content or instructional knowledge to qualify as competent technology teachers. While not surprising on its own, considering that Gess-Newsome et al. (2019) has reported similar findings for experienced teachers, there is much to consider about how teachers at any stage of their careers can strengthen their pedagogical content knowledge and skill (PCK&S).

It is from the perspective of the overlap of expertise, technical knowledge and skill, and PCK and PCK&S that this case study is positioned to investigate the potential relationships between

an expert teacher's technical knowledge and skill and PCK&S and pre-service teachers' understanding of the concepts conveyed, within the context of their own development.

Methodology

The case study framework of Merriam and Tisdell (2016) was used as the primary methodological guide for this inquiry. Their qualitative constructivist perspectives matched the purpose of the study and facilitated the emergence of the thick rich descriptions needed to comprehend the potential relationship between an expert teacher's pedagogical knowledge and skill, their technical knowledge and skill and the development of pre-service teachers' pedagogical and technical knowledge and skill. Merriam and Tisdell (2016) stated that "a case study is an in-depth description and analysis of a bounded system" (p. 37). Case and unit of analysis are analogous in case study research and is one of the fundamental features that delineate it from other qualitative methodologies (Baxter and Jack 2008; Merriam and Tisdell 2016; Yin 2014). The pedagogical and technical knowledge and skill of both the expert and pre-service teachers were the unit of analysis (the case) for this study as it was an intrinsically bound phenomena that was encapsulated within the wooden boat workshop program (Baxter and Jack 2008; Merriam and Tisdell 2016). The boundaries for the case included the winter wooden boat building workshops hosted by the Wooden Boat Museum and Faculty of Education, the workshop's instructor, and technology education pre-service teachers enrolled in the workshop as an extra-curricular opportunity. Since the study sought to understand a phenomenon that is deeply situated in context and was holistically and systematically bounded within an area that was not previously researched, it was situated as a qualitative exploratory case study. Within this methodological context, the following research question was proposed: How does an expert teacher's pedagogical and technical knowledge and skill influence the development of pre-service teachers' pedagogical and technical knowledge and skill?

Population Sampling and Data Collection

As there was only one instructor for the workshop, he was approached to volunteer for the study. The workshop instructor had more than 40 years of wooden boat building experience and approximately 15 years of instructional experience at the time of the study. He is considered an expert by his peers and the boat building community -locally, nationally, and internationally as demonstrated by a number of commissioned works for private and public organizations and his active contribution to the ongoing dialogue at conferences pertaining to wooden boats and their construction and heritage. As such, he was purposefully selected to participate in this study. Purposeful sampling was also used to establish the pre-service teacher participants. Students from the 2017-2018 Faculty of Education's technology education diploma cohort were approached to participate in the study. There were four potential positions available for pre-service volunteers out of a cohort of 20. Two students responded, one female and one male. Both pre-service teachers agreed to participate in the research study over the course of the twelve-week workshop. The female pre-service teacher had an English and religious studies background and the male a mathematics and computer science background and they represented a typical sample from the cohort.

Data were gathered over two separate workshops starting in the winter of 2017. During the 2017 workshop, a series of semi-structured interviews were conducted with the instructor along with researcher-as-participant observations, recorded in session journals. Three interviews in total were conducted with the instructor; two anchor interviews at the beginning and middle of the workshop based on my observations and journal entries and one post workshop interview. Sample instructor interview questions included: *1. What comes first for students –rules and piecemeal things (parts and order) or the bigger picture of design and pattern? 2. Are technical abilities more important that aptitude? 3. What role does knowledge play in teaching technical skills?* During the 2018 workshop sessions, the two pre-service technology education teachers engaged in prompted journal writing and post workshop semi-structured interviews as well. Sample pre-service technology education teachers interview questions included: *1. Were there any teaching techniques that helped you develop technical skills? 2. How did the relationship between you and the instructor influence your experience? 3. What was the role of peer interactions in your learning process?* Researcher observations and journals, instructor interviews, and pre-service teacher journals and interviews allowed for triangulation of data sources and methods. All interviews were digitally recorded and transcribed for analysis and pre-service journal entries were shared online with the researcher.

Data Analysis

Thematic analysis was utilized to analyze the interview, journal, and observation data. Specifically, the first and second cycle coding procedure of Miles et al. (2013) were used within the context of Braun and Clarke's (2006) six phase thematic analysis framework to uncover trends in the data. The interview transcripts were used as the primary source of data with the pre-service and researcher journals and observation field notes forming the context for triangulation of data sources and methods. As the data was read and re-read, preliminary codes and data chunks were created and identified in relation to the research question. A combination of summarizing words, in vivo, and process coding were used throughout this process. These codes were refined through a second cycle as meta-codes were created to facilitate the emergence of larger themes. These themes were then reviewed in relation to the whole data set to ensure each data chunk was located in the most appropriate category. The journals and observational field notes were then analyzed within the identified codes and were checked for new themes as well. Credibility (validity) of the study was increased through triangulation of data sources and methods, member checks, adequate engagement with the data, and data saturation (Baxter and Jack 2008; Bloomberg and Volpe 2012; Merriam and Tisdell 2016; Shenton 2004). Peer examinations were used to strengthen the dependability (reliability) of the study through the presentation of preliminary results for feedback (Baxter and Jack 2008; Bloomberg and Volpe 2012; Merriam and Tisdell 2016; Shenton 2004). The use of thick rich description and the selected sample also increased the transferability (external validity) of the findings (Merriam and Tisdell 2016). All participants agreed to participate through a process of informed consent with the acknowledgement that their identities would be difficult to conceal from the workshop participants and instructor due to the small size of

the group. They had the opportunity to select their own pseudonyms, but if they did not, their names were still changed to protect their anonymity from a larger non-localized audience.

Findings and Discussion

Throughout the wooden boat workshops that were the technological context of this study the instructor put forward the idea that the "truth is in the boat". That "… the boat in itself, as it comes together, answers the questions". This simple but profound statement encapsulates the idea of what lies at the heart of technical and pedagogical development within the context of pre-service teacher education and wooden boat building. That the technologies we create are much more than the final output of a technical process, they are embedded with an aesthetic that is representative of the technique, values, and culture of a continued time and place and as we literally shape the technology, in this case a boat, the technology shapes us. From an analysis of the data the idea of pre-service teachers shaping and being shaped through their interactions within their contextual milieu has come to light. Three major themes emerged from the data in relation to an expert teacher's influence on pre-service teacher pedagogical and technical knowledge and skill: interactions and relationships, technical knowledge and practice (skill), and pedagogical reflection and observation. The analysis of the findings will be discussed within the context of these three major themes

Interactions and Relationships

Interactions and relationships were emphasised by all three participants in this study and can be related back to the idea of shared experiences within a professional context as outlined previously by Collins and Evans (2018) and Dall'Alba and Sandberg (2006). Three sub-themes emerged from the data in relation to this larger theme: Instructor to student interactions, student-to-student interactions, and the development of mutually respectful relationships. All three sub-themes were identified as having an influence on both the instructor and pre-service teachers' own development within the technical and pedagogical spheres.

Instructor to Student Interactions

The interactions between pre-service teachers and the workshop instructor were viewed as essential to both as they learned and were shaped by one another. This was illustrated when the instructor talked about the relationship between his assumed technical and procedural knowledge and the perspectives that his students brought to the experience. In essence, the instructor was reflecting on the fact that even after years of working in this area, new perspectives can bring new insights for both him and the students involved. This idea was captured by the instructor when he made the following comment:

> *And you learn a lot from them [students] because even though you think that a thing you do, like, you thickness plane a board; well within that thickness planning of a board there's tons of information, there's tons of detail that you can assume because you've done it so often… but the student that are asking the questions sometimes brings to your attention, sometimes that proper or more, ah, a better way…*

As the instructor pointed out above, the importance of these interactions and allowing students the freedom to question methods and procedures can refine his own pedagogical and technical practice while allowing students to build their own. This idea of mutually learning both technically and pedagogically was also reinforced from the pre-service teacher perspective. When describing the teaching and learning of a difficult technical aspect of the boat construction, the female pre-service teacher reflected on the teaching approach used by the instructor. In particular, she was impressed by his ability to recognize a weakness in his own explanations and examples within this context, and his ability to adapt in the moment to meet the needs of the students. She remarked:

> *Seeing this play out was insightful for me and my own teaching because I thought that [the instructor] handled the situation nicely, by saying that it will become more clear when we start doing it and he'll go over it some more when we see more of it rather than just hearing the explanation.*

This type of interactions are the building blocks of developing cohesion within learning groups and again illustrate the relationship between the conceptual and tacit nature of the knowledge being accessed and used by the participants. What could not be conveyed in its entirety propositionally became a whole through the technical action directly illustrating Haye and Torres-Sahli's (2017) ideas about the holistic and bodily non-dualistic nature of knowledge.

Student-to-Student Interactions

Interactions between the workshop participants, including the pre-service teachers, were also encouraged, and facilitated by the instructor. While the instructor viewed peer-to-peer interaction as an essential part of his pedagogical practice, he was also aware of group dynamics over time. As people formed groups naturally he always monitored (a key aspect of an expert teacher as outlined by Auerbach et al., (2018)) to make sure no one person was dominating the action as there is little benefit in developing a student's own technical skills if they only watch others, they must do as well. As it is the instructor's belief that "… action will reinforce the lesson" he made an effort to move participants from group to group "…. to make sure that they have to do the action because the action is going to complement the knowledge..." This idea is a concrete example of the instructor's self-awareness of the interconnection between conceptual and procedural knowledge that has been identified as key in developing expertise in a domain (Haye and Torres-Sahli 2017; de Vries 2016). The female pre-service teacher also reflected on the role of group dynamics and the importance of learning from peers. This is vividly illustrated from an excerpt from one of her journal entries below:

> *Tonight, Chuck took me up to the boat and explained to me further the concept of the bevel on the boat. While the instructor explained this to me on paper and with the aid of the guide, Chuck brought me to the boat and showed me where the bevel applies and how it changes along the length of the boat, with it being the most straight towards the*

> *mid-ship bend. Seeing it this way made it much more clear to me, as I am usually a visual learner. Chuck was also very knowledgeable about this and had a very clear interest in this part, and it was great to share in his infectious enthusiasm as well as to be the member he decided to share this with. I understood the concept much more clearly though his explanation.*

This clearly demonstrates the distributed aspects of participating and learning technical skills within a group setting that would be comparable to other technology education learning environments. It also highlights the importance of meaningful relationships between peers throughout the entire process and again reinforces the socialization aspect of becoming an expert (Collins and Evans 2018).

Mutually Respectful Relationships

From a pre-service teacher perspective, the idea of trust and relationships between student and instructor and peer-to-peer was evident. Both pre-service teachers felt that without building trusting relationships learning can be hindered. The idea of reciprocating the instructional role with other participants was also highlighted as the female pre-service teacher mentioned feeling empowered when she was able to successfully teach another older participant a lamination technique. This feeling of empowerment is illustrative of the instructor's view about the importance of students learning from each other. This idea of relationship building was also very important between student and instructor. As the female pre-service teacher mentioned:

> *My favourite moments from him [instructor] was when I'd be stood up waiting for my part to come up or waiting for our board to come out of the planer, or whatever and he'd be there, "I've got to tell you ..., let me tell you about this story…" And just building that relationship made me trust him and trust what he was telling me even more when it came to him passing on an instruction.*

These seemingly simple and mundane interactions and experiences provided a platform for the instructor to gain insight into multiple aspects of his students in relation to such things as their technical background and interests. This information can be invaluable for pedagogy in practice or what Gess-Newsome, (2015) called the "act of teaching" (p. 36). As the male pre-service teacher commented, the instructor understanding the dynamics of a classroom "… comes back to knowing your students. Knowing how well they're doing, what their skill level is, what their comfort level is." This data complements the findings of Auerbach et al., (2018) that more than technical and pedagogical skills are at work in influencing pre-service teachers' development. It would appear that the interpersonal has a significant role as well.

The analysis of the data within this theme clearly illustrates the importance placed on instructor to student and student-to-student interactions within the larger social context of developing and maintaining positive supportive relationships. The data points to the importance of a

strong connection to both the instructor and the group in supporting the pedagogical and technical skill development of pre-service teachers. Their authentic and meaningful involvement within the sociocultural context cannot be understated in relation to the next theme: technical knowledge and practice (skill).

Technical Knowledge and Practice (Skill)

The importance of having or gaining a solid understanding and experience with the techniques of the contextual technical domain was a prominent theme that emerged from the data. As Shulman (1986) stated, pedagogy without content knowledge is useless, therefore understanding the relationship between the two is important because of the nuances between declarative and procedural knowledge that make up much of the content of technical domains. It is difficult to separate the technical from the pedagogical as the data would suggest an interplay exists between the two. Two sub-themes emerged in relation to the larger theme of technical knowledge: Instructor's technical perceptions and students' technical perceptions. Each of these themes lends insight into how an expert teacher's technical knowledge and skill may influence the development of pre-service teachers' technical knowledge and skill.

Instructor's Technical Perceptions

From the instructor's perspective, his educational and practical experience over the last 40 years has had a significant influence on his understanding of the declarative and procedural knowledge associated with wooden boat building. Combinations of informal and formal education within the context of personal necessity have shaped the instructor's technical perspective. The instructor recognizes explicitly the importance of multiple forms of knowledge and the relationship between conceptual and tacit. While he stressed the importance of declarative knowledge in understanding the bigger picture or concepts involved, he also noted "… you have to do, you have to use your hands, you have to use your mind, you have to, you know, but in particular you have to build". This is an explicit example of the tension between "knowing that" and "knowing how" and can be viewed as a point of transference of the instructor's conceptual knowledge into what Baird (2004) would call objective material knowledge. This tension is illustrated below as the instructor related the difficulty of expressing in words how to cut the angle of bevel on each frame when getting ready to plank a boat.

> *And to describe a curve in words, the metaphor; you can find metaphors for it, and I do seek them out, but the metaphor itself for it is not – it's only so small compared with the bending of a batten, and the connecting of the individual piece that we're working on. As you pointed out, the bevel, that batten takes that bevel from that frame at that point. Say it's frame number 3 the mid-frame in the boat, or one ahead or one aft of that, and explaining it now that bevel with the batten the visual of that tells you exactly the angle to cut, whereas the words prior to putting that batten on are weak.*

The instructor's self-awareness of these knowledge representation difficulties lies at the heart of the struggle of pinning down content knowledge within technology education. This self-

awareness has developed over many years as the instructor described a familiarity that allows him to make design and technical decisions fluidly where he generally focuses on smaller tweaks on a larger whole. This idea relates to Dixon and Johnson's (2011) idea that experts can make connections to common conceptual structures across disparate surface features while working in problem spaces, whereas novices cannot.

Students' Technical Perceptions

Pre-service technology education teachers reported developing greater confidence and ability with both general and specific technological knowledge throughout the workshop process. The male pre-service teacher remarked that his comfort level with various techniques and tools had increased through a combination of one-on-one and group demonstrations, and individual practice. Both pre-service teachers stressed the importance of understanding the sequence of a technical process before assimilating that process into the bigger whole. As the male pre-service teacher expressed:

> *Ok this is the skill that I'm learning, where do I start, what do I need, what's step one, what's step two, what's step three, and then I worry about how it fits in. Like, I worry about the hows and the whys and I worry about that later.*

Throughout the course of the workshop both pre-service teachers relied on the experience of their instructor as a model for building their own technical expertise moving forward. The pre-service teachers also related how they were constantly thinking about how the general and specific technical knowledge and skills they were developing could be applied to their own classroom situations in the future. While this modeling of instruction was specific to the boat building context, it also sheds light on the importance of this approach in other technology education related curricular areas. As Gess-Newsome et al. (2019) and Ramaligela (2020) have both reported mixed levels of content and instructional knowledge in pre-service and in-service teachers this type of self reflection may be one key to decreasing this deficit. While the procedural knowledge was an important aspect of student technical development, in this case as mentioned above, the wider picture of the task gave the procedural knowledge a solid context. The female pre-service teacher articulated the importance of this interconnection when she said:

> *I like steps. Like, if I can break something down, but I can't do a step if I don't see the purpose of the whole thing. So, I want a big picture, I want to see that we're making a boat, but OK now let's break it down and we're going to do the keel first and this is how we do it. So, here's five steps to making the keel. Let's go and get it together, and then I'll take you back and we'll relate it to the big picture for the next step.*

As illustrated above, the pre-service teachers had a good mental representation of the final artifact in question, something that is not always the case when students are engaged in open ended design problems (Dixon and Johnson 2011). Problem solving in this case was confined to

a contextually and culturally well-known artifact. Everyone generally had a rough approximation of what a small wooden boat looks like which may have helped the pre-service teachers deconstruct the task.

The data would suggestion that students found procedural technical aspects within the context of their instructor modeling techniques as useful for developing their own technical knowledge and skill. While the students did not directly discuss the explicit nature of technical knowledge, their ability to conceptualize the whole in relation to its parts may indicate the starting point for this inquiry. An inquiry that they may bring to their own pedagogical practice.

Pedagogical Reflection and Observation

Understanding student expectations and prior skill and experience was emphasised by all three participants in this study as a key theme related to their current and developing pedagogical knowledge and skill. Two sub-themes emerged from the data in relation to this larger theme: Relationship building, and the importance of modeling and reflecting on instructional practices. The data analysis has highlighted that these sub-themes had an influence on both the instructor's and pre-service teachers' pedagogical development.

Relationship Building

The instructor emphasised the role of understanding and building relationships with each set of students he encounters. He conveyed the importance of getting to know his students throughout the teaching process as a means of better meeting their needs. He generally broke this down into an informal process of conversation and observation driven inquiry. This informal, but systematic inquiry allowed him to ascertain students' self-perceived knowledge and skills in relation to the workshop content with his own observational evaluation of their actual level of competency, which he may judge below, above or accurate. Student driven questions forms one layer of this process that the instructor described as a valuable pedagogical strategy:

> *So, the more questions that individual is asking, it's sort of like a fog horn, you know, it's giving you directions, right. And so, for me, when I see some of the questions – hear some of the questions, I realize that some of the things have gone back a step or two prior to that question they're asking now was actually obvious the previous class. So, that gives me an alert to pay attention to that person and to bring them back and bring them to the boat if it's there, where it's done, and I could explain it.*

As illustrated above and corroborated from the field notes and my journal entries, these types of questions form organically throughout the process of the workshop and are not from the pre-conceived assumptions of the instructor and could be considered the personification of Gess-Newsome's (2015) PCK&S. The male pre-service teacher drew parallels between this questioning technique as a method of understanding everyone's differing ability levels and the importance of recognizing this in a K-12 technology education context. This pedagogical lesson

on the importance of applying different teaching strategies for different students was captured in an excerpt from his journal entry below:

> *For this project in particular, the huge divide between the various skills levels of the participants requires extra care taken to ensure that more competent students are allowed to work independently sooner, while less comfortable students may require more hands-on instructional time. This principle carries handily into the average Tech Ed classroom, where students will be coming from a variety of technical backgrounds and levels of interest in course content, and the instructor must balance the varied needs of all of their pupils.*

Gaining this type of insight into the standing of individual students, especially early in a course was reiterated by the female pre-service teacher. She emphasised building trusting relationships and the idea of having empathy for her future students when she stated:

> *We all stood around and like the 20 of us that started, we all had a bunch of different backgrounds, and experiences, and skill levels with all the stuff, but we were all nervous as hens at first because of everybody, maybe they're better, maybe they thinks that we're stund [sic] with this tool or whatever. Um, so, just knowing that, like, as a teacher all of my students are going to feel that way too…*

She went on to state that it was important for her to understand that her future students may have similar feelings within technology education courses and that she wished they could come to her class with a more level technological literacy to ease these types of feelings. Both pre-service teachers exhibit similar traits as Ramaligela (2020) found within a sample of other students, but they also exhibit a great deal of reflexivity about their own ability as technology teachers at this particular moment in time. This self-reflection within the context of their own experience may be a powerful indication of the influence working with an expert teacher may have on pre-service teacher pedagogical knowledge and skill development and is reminiscent to the master-apprentice relationship described by Laudan (1984).

Modeling and Instructional Reflection

The master-apprentice idea resurfaced in the second sub-theme as it focused on the observation of expert practice in relation to developing pedagogical knowledge and skill. While the instructor reflected on multiple teaching and learning experiences over his career, it was interesting to note the dichotomy in his own pedagogical practice and his first technical learning in this domain. He mentioned that many builders were not teachers in the traditional sense as illustrated below:

> *A lot of the builders, in particular the traditional builders of Newfoundland and Labrador, it was all look and see. You know, you had to – they were not talkative, you know. Some of them were, but I saw a lot of boat builders whose explanation was – they had no*

> *words for it, they showed you. And sometimes they wouldn't even show you, you had to look at them; you had to really just follow them around to find out what was on the go with certain fits and that.*

While this was one experience in a long list described by the instructor in his own path, the male pre-service teacher summed up the downside of such pedagogical practice when he stated that a "… teacher who knows everything is all well and good, but that doesn't help me if I can't figure it out". He also added that it was opportunities to observe different approaches throughout the workshop and other instances of instruction throughout his technology education diploma that helped him build a context for his own pedagogical practice. He noted that in addition to participating in and observing the pedagogical practice of the current instructor he had the opportunity to:

> *… add to getting to see how you [author] run a shop, getting to see how [university instructor] runs a shop, it was just another experience to sort of add to my list of, well this is – these are ways you can do it, so what works best for me.*

The opportunity to observe and reflect on the instructor's approach to teaching gave both pre-service teachers a chance to compare and contrast their own pedagogical understanding with that of an expert teacher. Again, this seems to point to the importance of a holistic approach to pre-service technology education teacher programming where a strong reliance on modeling and mentorship is key. Pre-service teachers need to understand that they are very much novices and that they have just begun a journey of technical and pedagogical development that will hopefully last their entire careers. With that being said, how do we best represent these ideas to pre-service students and educators?

Sociocultural Contextual Framework

Based on a review of the literature and the analysis of the data a descriptive framework has been developed to visually represent the relationship between the types of knowledge and skill and the importance of the sociocultural context in relation to pre-service teachers developing their own pedagogical and technical knowledge and skill. It is hoped that this framework may be useful in a meta-cognitive discussion of the roles and responsibilities of pre-service technology teachers and the experts charged with their education. Figure 1 illustrates this framework and its guiding concepts. Based on the complexity of trying to separate knowledge from action, the pedagogical and the content knowledge (technical knowledge) have been placed as the foundation of the framework as understanding these ideas and the relationship between them are viewed as paramount. They have also been joined to signify their interconnected relationship. Without a solid understanding of these concepts, it is very difficult for technology teachers to articulate their actions outside of a superficial descriptive stance. It is also important to note that the entire framework is also anchored to the actual technological activity that is being taught as illustrated by the inner square that connects all the elements of the diagram, again reiterating the idea that there can be no knowledge without activity.

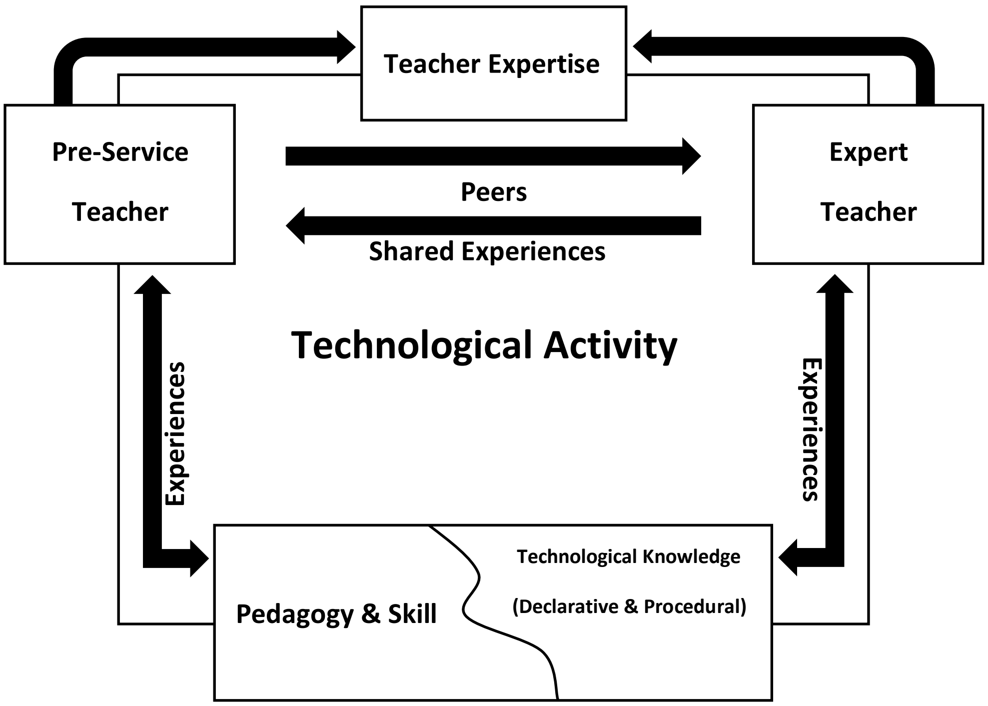

Figure 1: Sociocultural contextual framework of pre-service pedagogical and technical skill development

As a teacher (pre-service or expert) continues to gain experience within the pedagogical and technical domains, it is theorized that their expertise also increases as indicated by the bi-directional arrows connecting teachers with pedagogical and technical experiences. As they continue to gain experience in the pedagogical and technical, their expertise continues to grow. This is the case for both pre-service (novice) and established (expert) teachers. Although this is the case for both the novice and expert, the framework highlights that this development is not isolated to an individual. As the literature review and the data analysis revealed, there is a continual interexchange of shared experiences for both pre-service and expert teachers as they work through a technical activity together. This sociocultural context is also compounded by the shared experiences of classmates and other expert teachers through the course of the technological activity. What the framework does not account for is the quality of pedagogical and technical experience or the rate of expertise gained. The assumption for this study was that the quality of the pedagogical and technical experiences would be high, and as such, this is a significant limitation as this can not be guaranteed in general technology education classroom settings. This case study was not situated in a typical context; therefore, its transferability may be limited. Another limitation was related to the degree to which pre-service and expert teachers continued to gain expertise –was the gain linear or non-linear in relation to their experiences? These types of questions cannot be readily answered by this research design but could be addressed in further studies.

Conclusion

The data analysis and resulting framework has helped conceptualize and answer the main research question of the study buy succinctly highlighting the relationship between an expert teacher's pedagogical and technical knowledge and skill and the developmental pathway of pre-service teachers' pedagogical and technical knowledge and skill. Moreover, from the context of the wooden boat workshop not only is the expert teacher implementing a lesson on a technical skill, he is also implicitly delivering a pedagogical lesson as well. Therefore, from this perspective teaching and learning are a reciprocal activity in which the transfer of knowledge and skill is not a unidirectional action, but rather can be viewed as a partnership where all engaged parties benefit by increasing their expertise. While the framework is a very simple generalization within one local context of the complexity of how pre-service teachers develop their pedagogical and technical knowledge and skill, it nonetheless can be helpful as a planning and reflective tool for those charged with pre-service education and the pre-service teachers themselves. The idea that learning is a very social and interactive phenomenon is not something new to the educational research community, but those charged with undergraduate education must remember that their students will typically have a very basic and naïve formulation of the nature of teaching and learning. Therefore, it is very important to present research such as this, and more importantly, to make sure pre-service technology teacher education is configured to explicitly model and openly discuss these factors. While this study did not seek to quantify the types of activities or the amount of time required to develop expertise, it may be advisable to set up learning environments that acknowledge the reciprocal relationship between expert and novice and make explicit reference to the difficulty of understanding technical knowledge within the context of pedagogical practice. This may be one key to developing greater instructional and content knowledge for emerging technology education teachers.

References

Auerbach, A. J., M. Higgins, P. Brickman, and T. C. Andrews. 2018. "Teacher Knowledge for Active-Learning Instruction: Expert–Novice Comparison Reveals Differences." *CBE Life Sciences Education* 17(1). doi: 10.1187/cbe.17-07-0149.

Baird, D. 2004. *Thing Knowledge: A Philosophy of Scientific Instruments*. Berkeley; Los Angeles; London: University of California Press.

Baxter, Pamela, and Susan Jack. 2008. "Qualitative Case Study Methodology: Study Design and Implementation for Novice Researchers." *The Qualitative Report* 13(4):544–59.

Bloomberg, Linda, D., and Marie Volpe. 2012. *Completing Your Qualitative Dissertation: A Road Map from Beginning to End*. Los Angeles: SAGE Publications, Inc.

Braun, Virginia, and Victoria Clarke. 2006. "Using Thematic Analysis in Psychology." *Qualitative Research in Psychology* 3(2):77–101. doi: 10.1191/1478088706qp063oa.

Chi, Michelene T. H., Robert Glaser, and Marshall J. Farr, eds. 1988. *The Nature of Expertise*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Collins, Harry, and Robert Evans. 2018. “A Sociological/Philosophical Perspective on Expertise: The Acquisition of Expertise through Socialization.” P. 21 in *The Cambridge handbook of expertise and expert performance*, edited by Ericsson, K, R. Hoffman, A. Kozbelt, and A. Williams. Cambridge: Cambridge University Press.

Dall’Alba, Gloria, and Jörgen Sandberg. 2006. “Unveiling Professional Development: A Critical Review of Stage Models.” *Review of Educational Research* 76(3):383–412. doi: 10.3102/00346543076003383.

Dixon, Raymond A., and Scott D. Johnson. 2011. “Experts vs. Novices: Differences in How Mental Representations Are Used in Engineering Design.”

Doyle, Andrew, Niall Seery, and Lena Gumaelius. 2019. “Operationalising Pedagogical Content Knowledge Research in Technology Education: Considerations for Methodological Approaches to Exploring Enacted Practice.” *British Educational Research Journal* 45(4):755–69. doi: 10.1002/berj.3524.

Doyle, Andrew, Niall Seery, Lena Gumaelius, Donal Canty, and Eva Hartell. 2018. “Reconceptualising PCK Research in D&T Education: Proposing a Methodological Framework to Investigate Enacted Practice.” *International Journal of Technology and Design Education*. doi: 10.1007/s10798-018-9456-1.

Dreyfus, Hubert L., and Stuart E. Dreyfus. 2004. “The Ethical Implications of the Five-Stage Skill-Acquisition Model.” *Bulletin of Science, Technology & Society* 24(3):251–64. doi: 10.1177/0270467604265023.

Dreyfus, Stuart E., and Hubert L. Dreyfus. 1980. *A Five-Stage Model of the Mental Activities Involved in Directed Skill Acquisition:* Fort Belvoir, VA: Defense Technical Information Center.

Eraut *, Michael. 2004. “Informal Learning in the Workplace.” *Studies in Continuing Education* 26(2):247–73. doi: 10.1080/158037042000225245.

Ericsson, K., and Jacqui Smith, eds. 1991. *Toward a General Theory of Expertise*. New York: Cambridge University Press.

Gess-Newsome, Julie. 2015. “A Model of Teacher Professional Knowledge and Skill Including PCK.” Pp. 28–42 in *Re-examining pedagogical content knowledge in science education*, edited by P. Friedrichsen, J. Loughran, and A. Berry. London: Routledge.

Gess-Newsome, Julie, Joseph A. Taylor, Janet Carlson, April L. Gardner, Christopher D. Wilson, and Molly A. M. Stuhlsatz. 2019. “Teacher Pedagogical Content Knowledge, Practice, and Student Achievement.” *International Journal of Science Education* 41(7):944–63. doi: 10.1080/09500693.2016.1265158.

Haye, Andrés, and Manuel Torres-Sahli. 2017. “To Feel Is to Know Relations: James’ Concept of Stream of Thought and Contemporary Studies on Procedural Knowledge.” *New Ideas in Psychology* 46:46–55. doi: 10.1016/j.newideapsych.2017.02.001.

Hmelo-Silver, Cindy E., and Merav Green Pfeffer. 2004. “Comparing Expert and Novice Understanding of a Complex System from the Perspective of Structures, Behaviors, and Functions.” *Cognitive Science* 28(1):127–38. doi: 10.1207/s15516709cog2801_7.

Jones, Alister, Cathy Buntting, and Marc J. de Vries. 2013. "The Developing Field of Technology Education: A Review to Look Forward." *International Journal of Technology and Design Education* 23(2):191–212. doi: 10.1007/s10798-011-9174-4.

Kletzl, Sebastian. 2014. "Scrutinizing Thing Knowledge." *Studies in History and Philosophy of Science Part A* 47:118–23. doi: 10.1016/j.shpsa.2014.06.002.

Laudan, Rachel, ed. 1984. *The Nature of Technological Knowledge. Are Molels of Scientific Change Relevant?* Dordrecht: D. Reidel Publishing Company.

Merriam, Sharan B., and Elizabeth J. Tisdell. 2016. *Qualitative Research: A Guide to Design and Implementation*. Fourth Edition. San Francisco, CA: Jossey-Bass.

Miles, Matthew B., A. Michael Huberman, and Johnny Saldaña. 2013. *Qualitative Data Analysis: A Methods Sourcebook*. SAGE.

de Miranda, Michael A. 2017. "Pedagogical Content Knowledge for Technology Education." Pp. 685–98 in *Handbook of Technology Education*, edited by M. de Vries. Gewerbestrasse: Springer.

Mitcham, Carl. 1994. *Thinking through Technology: The Path between Engineering and Philosophy*. University of Chicago Press.

Ramaligela, S. M. 2020. "Exploring Pre-Service Technology Teachers' Content and Instructional Knowledge to Determine Teaching Readiness." *International Journal of Technology and Design Education*. doi: 10.1007/s10798-020-09570-5.

Ryle, Gilbert. 1949. *The Concept of Mind*. University of Chicago Press.

Shenton, Andrew K. 2004. "Strategies for Ensuring Trustworthiness in Qualitative Research Projects." *Education for Information* 22(2):63–75.

Shils, Edward. 1981. *Tradition*. Chicago: The University of Chicago Press.

Shulman, Lee S. 1986. "Those Who Understand: Knowledge Growth in Teaching." *Educational Researcher* 4–14.

de Vries, Marc J. 2016. *Teaching about Technology: An Introduction to the Philosophy of Technology for Non-Philosophers*. 2nd ed. Springer International Publishing.

Williams, John P., and John Lockley. 2012. "Using CoRes to Develop the Pedagogical Content Knowledge (PCK) of Early Career Science and Technology Teachers."

Yin, Robert K. 2014. *Case Study Research: Design and Methods*. 5th ed. Los Angeles: SAGE Publications, Inc.

Embedding Design Sprint into Industrial Design Education

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Abstract
Design Sprint is an intensive and innovation-focused framework based on Design Thinking principles. This study discusses the potential usage of the design sprint framework in industrial design education, and focuses on its strengths and weaknesses as an educational tool. Within this context, the study reports on a design sprint workshop involving twelve industrial design students in their fifth semester. The general process and outcomes of the design sprint workshop are critiqued along with the feedback of participant students. Design sprint in industrial education supports student ability to critique their own design and creative thinking, offers a new usage of prototyping as a testing material, and enables user-designer interaction, but also challenges the students with limited time and intensive workload. Design sprint can be a tool for carrying out multidisciplinary studies, reflecting the activities of professional practice, and accelerating project progress in design education.

Keywords
design sprint; design thinking; design education; educational model; industrial design; human-centred design

Introduction
As the centre of economic activity in the developing world is inevitably shifted from industrial production to knowledge creation and the service industry, innovation has gained a vital role (Brown 2009). This change has also affected the definition and practice of the profession of industrial design, related as it is to industrial production. An up to date definition of industrial design is that it is a strategic problem-solving process that drives innovation, builds business success, and leads to a better quality of life through innovative products, systems, services, and experiences (WDO 2018). Innovation has a significant role in industrial design, and the problem-solving process of industrial design can be encapsulated as questing for innovation. Cox defines creativity briefly as the production of new ideas, and innovation as the successful use of these ideas. Design, on the other hand, creates a link between creativity and innovation, transforms ideas into attractive and practical solutions for users and customers, and in doing so becomes purposeful creativity (Cox 2005).

Nowadays, the problem solving and innovation questing methodology of designers is used in a wide variety of areas. Over time, the definition of industrial design has been updated to include designing beyond the physical product (systems, services, experiences, businesses) and innovation. Systems, services, experiences and businesses are problem areas waiting to be designed. Design thinking is the methodology of the designer in approaching these problems, in solving them, and in the search for innovation, and it has contributed to the evolution of different methodologies. Design sprint is one of the methodologies which derives its roots from design thinking and other approaches and it is both flexible and easily applied to given circumstances (Banfield et al. 2016). Design sprint is a highly condensed approach which is used

in the field of entrepreneurship and which takes its originality from its limited time period and intense workflow. Developing a solution to the problem, taking advantage of other disciplines in the solution development process and creating links between different components are inherent in the design action and design education. The constructivist structure of design thinking methodology has yielded it to be used as a tool for design education. As design sprint is one of the notable frameworks of design thinking, it is worth asking if design sprint can be used in a similar manner. This study examines whether design sprint has a similar kind of potential in design education and discusses ways of implementing an entrepreneurship application in industrial design education. It differs from other studies in the field by adapting Jake Knapp's framework to the industrial design discipline. In order to do that, a design sprint workshop with undergraduate level industrial design students was carried out and the process and results of the workshop analysed. This study has been constructed upon the theoretical basis of design thinking and design sprint, educational applications of design sprint, and the process and outcomes of the design sprint workshop.

Background

In this section, firstly the concept of design thinking is set out, similar methodologies and approaches that focus on innovation are shared and the relationships between them revealed. Then the design sprint framework, which is the subject of this study and an innovation-oriented approach, and the studies conducted using this framework are described. In this way the theoretical framework of the workshop actualized in industrial design education was constituted.

Design Thinking

Two current discourses can be mentioned related to the concept of design thinking. These two discourses are (1) working practises of designers, which is directly related to design, and (2) human centred problem-solving approach for decision makers to solve wicked problems of the real world, which is connected to the fields of management and business (Johansson & Woodilla 2010; Melles 2010). Whilst the first discourse of design thinking expresses the designers' practices and how they think while working and constitutes an academic field with a history of about fifty years, the second one is an innovation and value creation method for better business success and is newer than the first discourse (Hassi & Laakso 2011; Johansson & Woodilla 2010). In the continuation of this study, the term 'design thinking' is used to define the human centred problem-solving approach as explained in the second discourse.

The late 1990s and early 2000s can be seen as the period during which design thinking really emerged; since then its recognition has increased and it has begun to be used beyond the design discipline. IDEO, a Silicon Valley based design firm, was one of the pioneers of this popularization process. Design thinking can be described as a discipline that uses the designer's sensibility and methods to match people's needs with what is technologically feasible and what a viable business strategy can convert into customer value and market opportunity (Brown 2008). It is a collaborative, team-based and interdisciplinary learning process of observation, framing, ideation and solution development (Beckman & Barry 2007; Curedale 2013). This process generally starts with a problem or a question instead of an idea (Mueller & Thoring 2012).

The concept of design thinking can be summarized as human-centred approaches, and it has been handled by a variety of institutions that have often named it differently. These approaches used in the new product development and innovation process are as follows:

- Human Centered Design → IDEO Foundation (The Field Guide to Human-Centered Design 2015),
- Design Thinking → D.School ('An Introduction to Design Thinking' n.d.),
- Double Diamond → Design Council (Innovation By Design 2015),
- 3 Gears of Business Design → Rotman School of Management (Fraser 2009).

Despite the varying terminology, there are notable similarities between the different methods and processes shared under the human-centred approach. Starting with empathy, including divergent and convergent stages, being fed by the user, or even including the user in the processes, are all examples of the similarities between them.
There are also methods and processes with similar characteristics which can be grouped within a customer-centred approach while being closer to the business perspective used in innovation seeking and new product development processes:

- Customer Development (Blank & Dorf 2012),
- Lean Start-up, Build-Measure-Learn Feedback Loop (Ries 2011),
- Business Model Generation / Canvas (Osterwalder & Pigneur 2010),
- Running Lean, Lean Canvas (Maurya 2012).

There are many common aspects between human-centred approaches and customer-centred approaches. Both approaches start from potential customers, collect data from them, and involve customers, potential users and other stakeholders in their development processes. In both approaches, ideas and prototypes are developed by revising them with potential user feedback, and they are both based on learning and identify the process as a cycle rather than a linear process. Although they apply similar methods and tools, they use different names in the process. In human-centred approaches, iteration usually takes place at the test stage through the prototype towards the end of the whole process, while in customer-centred approaches, it is called pivoting, and can be implemented earlier, not only in the prototyped idea, but even before the hypothesis is tested (Mueller & Thoring 2012).

The common feature of customer-centred approaches, which distinguish them from human-centred approaches, is the search for the profitability and the profit which is also included in the definition of the enterprises and ventures. In addition to this, there are several other main differences between these two approaches. When it comes to the questing for innovation and new product development process, in general human-centred approaches are focused on innovation, while customer-centred approaches focus on innovation for enterprises, especially for technology start-ups. In human-centred approaches, the idea is built throughout the process, while in customer-centred approaches, there is generally an initial idea and hypotheses are tested in the process. While human-centred approaches use the tools of many different creative disciplines, customer-centred approaches have specialized tools such as canvases. While qualitative evaluation is made in human-centred approaches, qualitative and quantitative evaluation can be made in customer-centred approaches.

In this section, the variously named approaches based on the concept of design thinking have been generalized as human-centred approaches, and approaches with similar features but more of a business perspective have been described as customer-centred approaches. An effort was then made to reveal the similarities and differences between these two approaches. In the next section, design sprint will be addressed, another methodology focused on innovation feeding from the design thinking perspective.

Design Sprint

'Design Sprint' is an intensive methodology and framework that aims for innovation based on design thinking principles. Banfield et al. (2016) state that it evolved from and is comprised of a number of different approaches such as design thinking, agile, etc., and it is a flexible product design framework, not a set of rules, which can be tailor made for different teams and needs. It is a step by step one-week process which can be used by any development team or organization.

Like the customer-centred approaches mentioned above, it is especially popular in the technology start-up ecosystem, probably because of its origin. During their working experiences in Google and Google Venture, Knapp et al. (2016), developers of design sprint, observed that strict deadlines, focusing on individual work, and giving time to prototype are more productive than traditional workshops which consist of noisy brainstorming and group discussion sessions. Design sprint and its core principles developed from these key ideas.

Knapp et al. (2016) define a five-day process for running design sprint as below:

- Day 1 (Monday): Structured discussions to create a path for sprint. At this stage, the long-term goal is established, sprint's challenge map is created and the process continues by obtaining knowledge from the company's experts. Finally, the ambitious but manageable target point of a solution within one week is arrived at.
- Day 2 (Tuesday): With the help of the decisions and target point established on the first day, Day 2 concentrates on solutions using structured ideation and sketching methods.
- Day 3 (Wednesday): Decision making day for the creation of a prototype and its testing based on one of the solutions created on Day 2. The team then creates a storyboard which is also a step by step plan of the prototype.
- Day 4 (Thursday): Prototyping day. The team creates 'fake' and realistic prototypes for testing the following day.
- Day 5 (Friday): Decisions and hypotheses of the team are tested via prototypes with real people.

This is a very quick timebox approach and an essential practice for organizations which are serious about innovation but have no time to do user studies (Banfield et al. 2016; Mikkonen 2013). Due to the whole process and its stages being defined in a timebox, the need for preliminary preparation and data are necessities for design sprint.

Although it is presented as a general approach and framework for innovation, it can be said that its suitability depends on the particular case. Mikkonen (2013) states that it is more suitable for generating concepts from imaginable topics, such as user interfaces or mobile

devices, generally the subjects of technology start-ups. Banfield et al. (2016) indicate that it can be less helpful if the product is well defined, if there is an additional research need, or if a business opportunity is not clear. This is supported by the fact that design sprint starts with discussions and the sharing of knowledge between organizations and consists of testing and revising a hypothesis.

There are some recent studies comparing design thinking and design sprint, which can be helpful to understand the concept better. Figueiredo & Fleury (2019) compare design thinking and design sprint, reporting their relative advantages and disadvantages:

- Design Thinking builds something totally new; understands the context in depth and then creates a solution; has a 'learn by sharing' character; uses prototypes with a more general character that can simply be for describing a possible solution; stems from the will to look at the needs users are facing and help them in finding a solution; and involves processes that can last hours, days, months or even years.
- Design Sprint creates a workable solution; develops MVP (most viable product) quickly; has a 'learning by doing' character; simulates working prototypes; comes from an internal company challenge; and has a defined duration of 5 business days, from Monday to Friday.
- Figueiredo Correio and Fleury (2019) also compare design sprint and design thinking, then summarize the advantages of design sprint in three points:
- Owing to the one week long, well-defined and clearly structured nature, it has a low experimentation barrier.
- By involving executives, especially at the decision stages, solutions can be compatible with the company's plan.
- As with the lean approach, focusing on the priorities and testing with real users, its orientation is incremental innovation.

Design sprint, which is a customized framework based on the design thinking approach, can be appropriate for various needs. It may not be correct to compare design thinking and design sprints directly since they are not equivalent or contrary to each other. However, this comparison is still required in order to position the concepts relative to one another. In the next section, studies which use design sprint, especially in the field of education, will be discussed.

Educational Usage of Design Sprint

In order to have a solid discussion on how to use design sprint in the industrial design education process, related studies which have actualized design sprint in educational environments and characteristics of industrial design education need to be examined.

In the search for related studies, only a limited number of studies and examples were found. The reason for that may be the newness of the design sprint framework. The majority of examples reached were related to computer science education. Ferreira and Canedo (2019) conducted a study investigating how design sprint can be adapted to Information Technology undergraduate education. Following their case studies, they claim that the process needs a longer time period and they state their intention to test it over a full academic semester

(Ferreira and Canedo 2019). Larusdottir et al. (2019) emphasize the disregard of Human Computer Interaction (HCI) and User Centered Design (UCD) in the field of education when considering their methods and practical usage. After their two-week intensive UCD summer course, Larusdottir et al. (2019) observed that the main problems of the students were time management and user involvement. Raubenolt's study was not actualized in the education environment but obtained similar results. After implementing design sprint and conducting a survey with participants, Raubenolt (2016) suggested that the design sprint process requires more time especially for prototyping and sharing with the team the summary of the problem and educational material before team members can be prepared for the process.

In industrial design education, studio/project-based approaches have been quite common. The studio is a simulation of the professional working environment and the content of the studio methodology consists of several steps of the design process, such as sketching, conceptual design, final jury, etc. (Oxman 1999). In the studio approach, students are expected to experience design processes as they would in their future professional life. Overbeeke et al. (2004) describe projects and assignments in design studios as the doors which lead students to the path of a designer's knowledge, skills and attitudes. Cross (2001) emphasizes the intellectual culture of design itself, and the idea of design education nourishing it. In this respect, contemporary tendencies and changes in design culture reflect upon design education. New approaches related with design evolve over time and design education walks arm in arm with these new approaches. For design thinking, it has been the same. Wrigley & Straker (2017) point out the nexus between the process of design thinking and the five themes of design thinking courses, which are 1) theories, methods and philosophies, 2) product focus, 3) design management, 4) business management, and 5) professional development. So the effect of design sprint upon education will inevitably be seen due to the nature of design.

Thomas and Shin (2016) apply a similar method to design sprint in industrial design education, giving it a similar title, Educational Design Sprint. However, Google's design sprint did not have any particular starting point of process setup, stating that they realized it later. The Educational Design Sprint of Thomas and Shin (2016) is a 3-5-week process consisting of 7-9 lessons. They also compare corporate design process with the design sprint process, finding that design sprint has fast phases with not much market or user research, and fewer iteration phases than design process. They mention that their intention was not to identify which design process is superior and they point out that there are many lessons for students to learn by exploring product development with different approaches.

There is another study which aims to integrate design sprint with research carried out in the Netherlands in the domain of health and wellbeing. Action Design Research (ADR), which is a combination of Action Research (AR) and Design Research (DR) proposed by Sein et al. (2011), is an approach to design IT artefacts in a problem inspired and action oriented setting which starts with a practical problem in an organization (Keijzer-Broers & Reuver 2016).

Keijzer-Broers and Reuver (2016) integrate design sprint to ADR process for a quick launch into the design process, because of the budget and time constraints in ADR projects.

Considerable potential has been seen in the application of the design sprint concept to design education, in terms of improving students' problem-solving capability and addressing the lack of case studies actualized within the scope of design education.

Methodological Approach

The aim of this study is to find out how the design sprint framework, which is one of the structured questing innovation tools, can be used in industrial design education, and to reveal which aspects of it work and which are ineffective. It was considered worthwhile to investigate how industrial design education, which aims to add professional skill to students via the experience of different methodologies in new product development and problem-solving processes, will interact with design sprint. Since this study searches for the impacts of design sprint approach on industrial design education, participants of the education system, in this case students, were involved in the research process. Within the scope of this study, a design sprint intervention was made in the area of industrial design education, following Jake Knapp's framework. This intervention took the form of a workshop and its impacts were evaluated in the light of the data obtained.

This study is based on the design sprint workshop held at the end of the fall semester of 2019 in the Industrial Design Department of Al-Zahra University in Iran where the researcher was a guest lecturer for a limited time. Volunteering participants of the study were 12 students who were in their fifth semester of an eight-semester undergraduate level industrial design course. Since the university specialized in the education of women, all participants were female. The participant students were classmates, so they were familiar with each other, but they first met the researcher during the workshop. In this study, the researcher served as the executive. The researcher has had experience in running Design Thinking courses and workshops with both undergraduate level and graduate level students from the industrial design and other disciplines. Thus, the researcher was able to evaluate the required adjustments during the workshop.

A variety of qualitative data collection tools were used in this study. Throughout the design sprint workshop, the researcher made detailed observations on the process of participant students. Carr & Kemmis (1986) stress the essential requirement of understanding other actors in the transformation process in an action, so in addition to observation, participants were asked to keep a diary at the end of each workshop day and share it with the researcher at the end of the process to comprehensively report on their workshop experience. 'Diary', as a kind of writing method, preserves the reflections of its owner, helps to recapture and intensify the experience, supports learning, and also gives clues about the owner's insight (Walker 1985). Thus, diaries in the design sprint workshop provided a closer look from the participants' point of view. Finally, after the design sprint process, feedback was received from the participants with the help of a questionnaire containing open-ended questions. Applying different data gathering techniques in this study helped to get detailed information about the process and to create data triangulation which is defined by Yin (2016) as a way of strengthening the credibility of a study by finding convergence on outcomes. As Creswell (2009) explains, following the collection of data, a group of themes emerges from the process from which research results can be drawn.

Design Sprint Workshop with ID Students

The structured step by step framework that Jake Knapp created was used as a reference, and some revisions were made while planning and running the workshop. First of all, the design sprint, which originally required a 5-day period, was shortened to 3.5 days due to time constraints at the case study university: On the first day, the understand and define stages; on the second day, the sketch and decide stages; on the third day, the prototype stage; and on the last half day, the testing stage was actualized via relevant methods (Table 1).

Table 1: Structure of The Workshop

Day	Design sprint workshop structure	What was done at this stage?	It was done by…
1	Understand stage	Determination of the starting point	dot voting between the variety of products of students
		Creation of imaginary company	writing sticky notes about the company and then dot voting between them
		Asking the experts	role playing as if students were the experts in the company
		Capturing ideas	writing sticky notes with "How might we" questions
		Determination of goals and questions	writing variety of goals and questions on sticky notes and dot voting between them
		Persona creating instead of mapping	writing characteristics of users
	Define stage	Define the target users and target problems	dot voting between "How might we" questions which were organized into groups
2	Sketch stage	Lighting talks	giving information about other companies, market and relevant other products and concepts
		Sketching the ideas	four step sketching: 1) notes, 2) ideation, 3) crazy 8s, 4) solution sketches
	Decide stage	Art museum	sticking sketches to the wall
		Heat map	using multiple votes for the exciting ideas on the sketches on the wall
		Speed critique	explanation of the ideas by facilitator
		Straw poll	selection of projects using only one vote
		Supervote	grouping the highest voted projects into two and working with both projects instead of CEO vote
3	Prototype stage	Making prototype	developing prototypes by using appropriate tools, advancing from storyboards, division of tasks and creating the prototype model by only one person and trying it.
3.5	Validate stage	Testing the prototype	interviewing 5 users for each product

Before running the workshop, the researcher prepared a presentation that included theoretical knowledge about design sprint and its stages. Thus, at the beginning of each stage, it was possible to share the relevant theoretical information about that stage with the participants. In design sprint, the first requirement is a starting point. For this purpose, the students were asked to bring products they use in their daily lives to create a starting point for the process and to facilitate the processes that require preliminary research such as the usage scenario and market of the product. Products brought and shared by students ranged from glasses, a smart wristband, a thermos, and a computer mouse, to a french press. There were both low- and high-tech products. Using the dot voting method, which is often used in the design sprint process, the product/subject to constitute the starting point of the study was determined democratically (Figure 1). More than half of the students chose a thermos.

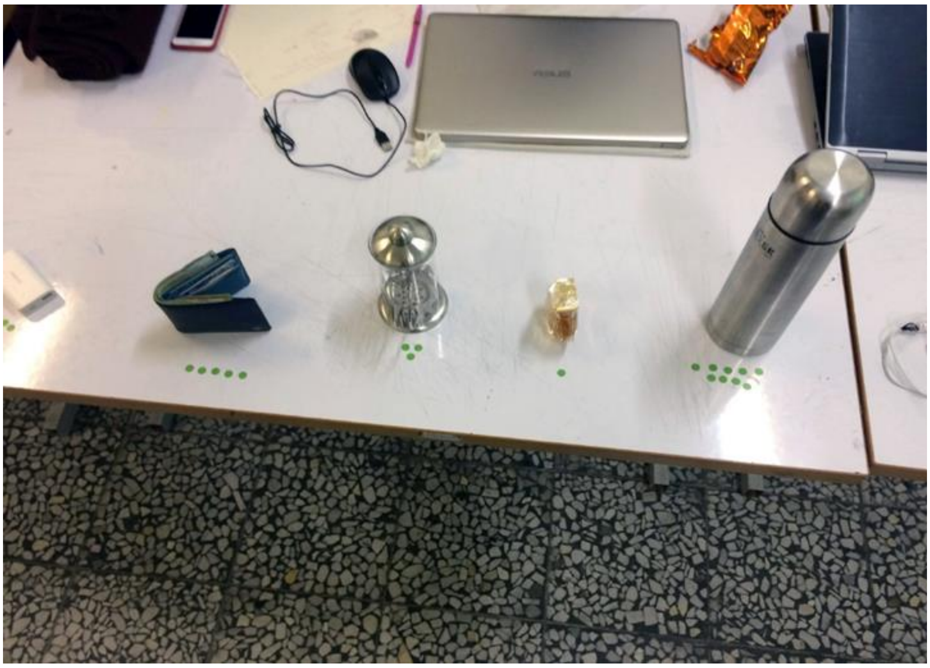

Figure 1: Design sprint object selection process.

As this study was carried out in the educational environment, the first step was to create an imaginary company. Participant students were asked to think of themselves as the staff of a company that produces thermoses, and one of the students was assigned as the facilitator of the workshop. Role playing activities and other stages of design sprint were realized through this company and its features. In addition to this change to the design sprint method, at the end of the second day, a revision was made before the prototyping stage. Since the company was artificial and there was no CEO to supervote, ideas with the highest number of votes were grouped into two themes. Then the student group was divided into two parts and both teams were asked to prototype their projects according to the themes. During this process, students were sometimes overwhelmed by the duration of the phase and occasionally the facilitator student needed support. At such times, additional time was given to the students and the researcher gave the required support to the facilitator. Apart from these necessary revisions, as far as possible, the nature of design sprint was adhered to.

Limitations of the workshop

Prior to discussing the results of the workshop and the potential of the design sprint framework in industrial design education, major constraints of the study need to be considered. First, depending on the duration of the workshop, the allotted time of the stages in design sprint framework was reduced. Especially in the prototyping stage, the combination of the students' performance in the usage of design tools, lack of required equipment and space, and shortening time affected the process. In addition to the challenge of creating testable prototypes in a limited time, the participating students focus on small details and being unable to create high fidelity 3D prototypes in such a short period ended up using 2D presentations of the products as testable prototypes. The sprint was actualized through an imaginary company. Thus, on the contrary to running a design sprint in an existing company, the participants of the workshop could not get the required data beforehand. In addition to that, dealing with an imaginary company and being run in an educational environment in a very fast phase caused a lack of a specialist's evaluation on the stages of the design sprint.

Results

The imaginary company, created by participants after the dot voting of subject/ artefact, was named TAF. A fictional company history was outlined: TAF was founded fifty years ago for the production of traditional teapots in Iran, then extended its product portfolio to other metal kitchen appliances and was currently looking for new products and solutions for global markets (Figure 2).

Figure 2: Fiction of TAF.

Firstly, students made selections between the alternatives of goals and problem areas of the company and “How might we” questions by dot-voting (Figure 3). The highest rated goals of the company were:

1. Using new technology in our product in raising the time keeping
2. Using new material and becoming ‘smart’
3. Using new designing and producing methods.

Questions that students wanted to find answers to in the sprint were:

1. Which materials could be more suitable in terms of production and usage?
2. How can design be pure and minimal?
3. How can we increase the usage of our product?

“How might we (HMW)” questions which got the highest votes of students out of 51 alternatives were:

1. HMW make self-heating and portable ruhi dishes?
2. HMW omit metals from our products?
3. HMW make less waste?

Figure 3: HMW questions.

Once the target users and target problems were defined by the students, the sketching stage was carried out by considering the outcomes of the previous stages. Students drew their ideas anonymously, using the same kind of paper and pencil. Students created solutions and voted on the ideas. Since this workshop was actualized in an educational environment and there was no CEO to decide which ideas to pursue, the highest voted ideas were grouped under two themes and the participants were split into two different teams. Two different thermoses for TAF were designed by two different groups according to the criteria they set at the beginning of the design sprint. The groups visualized the usage scenarios of their products during the prototyping stage and created photorealistic renderings. In addition, they integrated the thermos, a physical product, with digital solutions such as mobile applications and created examples for the interfaces of these digital solutions.

The first group concentrated on mountain hikers and climbers and developed a thermos with the requirements of this user group (Figure 4). Possible features of the mountain hikers' thermos were identified as easy to hold and carry, chargeable self-heating, easy to clean, easy to find thanks to neon colours etc.

Figure 4: Thermos for mountain hikers and climbers developed by the first group.

The second group aimed to facilitate the use of the thermos for a more general market and developed solutions for this (Figure 5). Stability problem and tilting, having no idea about the temperature of the liquid in the product, possible negative experiences of visually impaired people, and losing the product and being unable to find it were problems that they tried to solve.

Figure 5: Thermos for all developed by the second group.

Since the developed solutions were mostly physical artefacts and due to time constraints, presentation posters in A3 size paper and marketing materials consisting of photorealistic visuals were created in the prototyping stage for the testing stage. These marketing materials were product pages in shopping sites such as Amazon or flyers (Figure 6). Each group tested their products with 5 people.

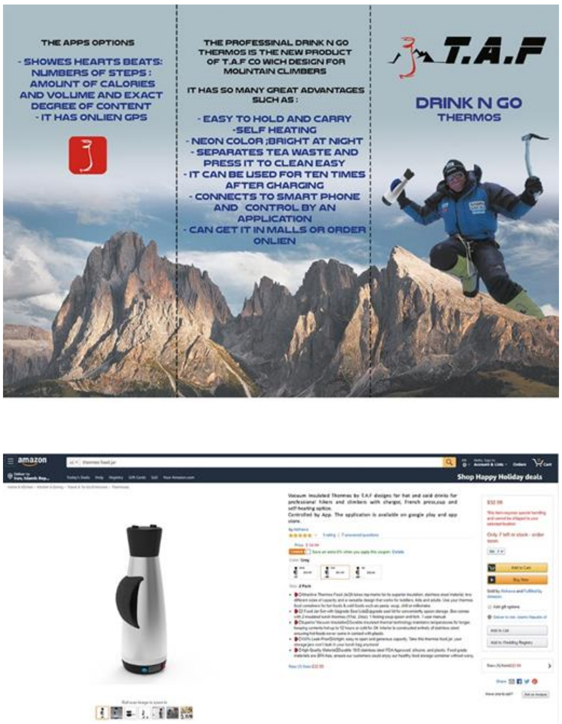

Figure 6: Amazon page of the product and flyer.

Since the process was analysed via student feedback collected by questionnaire, diaries and observation, many positive and negative inferences could be made. The questionnaire aimed to evaluate design sprint practice in the educational context by asking students the following open-ended questions:

1. What did you learn from the Design Sprint Process?
2. How could it be improved?
3. Is there any negative aspect in this process?
4. Are there any similarities or differences between your previous processes and Design Sprint?

Diaries reflected the experience of the students. Observations helped to analyse the impacts of the design sprint intervention. After analysing the questionnaires, diaries and observations, it can be said that the positive themes were: democratic characteristic of the process, being able to be a decision maker in an educational assignment, having group work but being able to work individually within the group, visualizing every action, ease of finding a starting point, self-confidence coming from the anonymity of the sketches, understanding the relations between industrial design and other disciplines, understanding the importance of prototyping and testing, not having homework, and having an organized process. The intensity of the process, and lack of time at the prototype stage were the two main negative themes.

It is a common method to have a master-apprentice relationship in design education and the students' work is criticized, verified or falsified by the advisors so that students can continue the development process of the projects according to the comments of their advisors. In the design sprint framework, the project development process continued in a more democratic way via a structured process and tools, and the testing of the idea to be verified or falsified was left to the testing stage. The students said that the design decisions they made were not labelled as wrong by an educator in the process, and this made them feel more comfortable. One of the students stated:

> *It was almost one of the first times that I could choose what I like and which way I want to proceed, a professor didn't take part and no one was making my decision.*

Similar to the decision-making aspect, in traditional studios, students have no power over others' projects and have no chance to follow their design decisions besides group critiques and juries. Thus, progress in the project is actualized only within the student's own perspective. In the design sprint workshop, everyone was able to follow all ideas and vote to improve them. This gave the students freedom in all phases. One of the students even admitted, "I really loved voting for our decisions."

In addition, some stages of the process such as prototyping, provided opportunities for dealing with activities that they liked and were interested in, and this was another point emphasized positively by students. At the prototyping stage, students had the opportunity to share work according to the subjects they are more interested in, such as graphic work, copywriting or 3D modelling. Facilitating the decision-making processes via tools and methods such as dot voting, and making group work more productive, by 'Working Together Alone' compared to brainstorming, etc., were other points positively evaluated by students. One of the students explained it in the following way:

> *Honestly, I like giving ideas alone, I'm not saying that I don't like work in a group and it's not efficient. I'm saying that I like to imagine and sketch it by myself then have my friends' suggestions to improve it.*

Anonymity of the process made students comfortable:

> *The other one is that the whole class had to use the same colour for writing and they mustn't write their names, so they can write with comfort and there will be no bias. No one is better or worse than anyone else.*

It has been stated as a positive aspect of design sprint process by many students that the project development process in traditional design studios and design education consists of intense work which continues outside the studio as homework, while design sprint workshop, on the contrary, involves no homework assignments, the whole process being done in the studio environment during the day.

As the negative aspect of the design sprint process, most of the students mentioned the problem of time limitation. Design sprint is already an intensive process, and as the current study was carried out in a university where the researcher was working as a guest lecturer, the study duration was, by practical necessity, shortened further to just 3.5 days. At almost every stage, time extension was given according to the demands of the students. For example, the solution sketching stage was planned as 90 minutes, but extended to 120 minutes. Many students have stated that the process was very intense and that if they had had more time, they could have done much better. In addition, the students stated that they were more energetic in the morning hours, thus they could concentrate better on the problem, and their fatigue increased in the afternoon studies. One of the participant students who found the process intensive and exhausting mentioned that despite this negative aspect she was willing to repeat the process:

> *To be honest at the end of the last week I was so happy that it was over and I get to have some rest (of course not because of your class but because of the crazy timings) but now when I look back at the experience I wish that your class and that whole week could happen again, like once or even twice in a every month actually! That's how much I enjoyed it. I'm still in shock and I can't believe how much work we've done and how much I've learnt during the past week.*

Another important point of the design sprint process that distinguishes it from the traditional design studios, is that instead of a jury consisting of studio executives, their design decisions were verified or falsified by potential user interviews and testing (Figure 7). It was a substantial achievement for students that they directly experienced that some of their decisions and assumptions were perceived differently by potential users.

Having an organized structure, design sprint practice helped students to complete the task, and the multidirectional, democratic structure of the design sprint approach positively affected the project development process.

Figure 7: Potential user interviews and testing.

Discussion

There are significant similarities between the results of this study, actualized for the purpose of how to use design sprint framework in industrial design education, and previous studies. As Figueiredo and Fleury (2019) state, the well-defined and structured nature of the framework eased the experimentation. The fact that the researcher had already had experience as an educator in industrial design can be said to have had a facilitating effect. Thanks to this experience, it was possible to restructure and tailor the process according to immediate needs and reactions, by manipulating the duration of some of the phases and supporting the students if they faltered at any point in the process.

Similar to workshops held by different disciplines before, time problems were frequently encountered throughout the process (Ferreira & Canedo 2019; Larusdottir et al. 2019; Raubenolt 2016). However, this problem was not encountered at every stage of the process. For example, combining the sketch and decide stages in one day, which were defined as two separate days by Knapp et al. (2016), did not cause a big problem. Conversely, especially in the prototyping stage more time was needed. This may be due to the fact that students were still in their fifth semester, and their practice and speed in using related digital tools was still being developed. When similar studies are carried out with seniors, the time problem may decrease. It was very strongly emphasized that the prototyping stage is for testing the solution rather than creating presentation material. However, the instincts of a design student, being a nit-picker and going into every detail, negatively affected the prototyping stage. In addition, the time and effort difference between the creation of a testable prototype of digital solutions and physical solutions was another challenging factor. As Mikkonen (2013) states, the framework is more suitable for imaginable topics such as creating user interfaces or mobile device solutions. To create physical testable prototypes in a limited time may require a more qualified team and workshop facilities, and it might be one of the biggest challenges of adapting this framework to industrial design education.

In this study, the subject of the sprint was determined via dot voting by the participants, and then the data and imaginary company needed in the process were also created by the students. This freedom and the participatory method made it easier for participants to adopt the issue and the problem. However, even if the design sprint process had been planned by acting from an existing company, it may have been easier to provide the data needed beforehand, especially for the initial stage of the process. Thus, for students who started the design process with intensive user and market research in an ideal scenario, this phase may be overcome more easily with the help of concrete data as opposed to imaginary data. In addition to that, due to the fictional nature of the workshop, even though the proposed solutions came closer to the sprint target, they did not fully cover the sprint questions and HMWs.

When comparing the traditional studio approach and the design sprint intervention, it can be said that although the students achieved similar results with the traditional design process, the path they followed was different based on the nature of the design sprint. Being able to improve projects from a collective perspective, not feeling a hierarchy in the educational environment, understanding the connections of industrial design with other disciplines from the first hand and understanding the importance of user testing, feeling of democracy and independence separate design sprint from the traditional studio approach.

The approaches and methodologies used in the questing for innovation process are categorized as customer-centred approaches and human-centred approaches in the literature review section. Design sprint may be included in the category of customer-centred approaches due to its features of being closer to the business perspective and being used for technology start-ups by Knapp et al. (2016). In addition, this framework and the others in the customer-centred approach category can be demonstrated in practice to the senior design students, so they can gain awareness in different problem-solving methodologies. Finally, the design sprint framework in the educational environment ensures that senior students who are trained in different departments can work on the same subject. This experience may be one of the most suitable and memorable simulations of professional life that students are offered.

Conclusion

In this study, the relationship between design sprint and similar approaches focused on innovation has been revealed and how this framework can be used in industrial design education has been examined. A three-and-a-half-day workshop was held with the 5th semester students in the Industrial Design Department of Al-Zahra University in Iran. The most important problem encountered according to the feedback received at the end of the process was the intensity of the process and especially the problem of limited time for the prototyping stage. Realization of the whole development process within working hours, freedom to continue their development processes until the testing stage without being falsified by a higher authority, possibility of dealing with the activities they are more naturally inclined towards, and tools and methods such as dot voting and 'Working Together Alone' in the process were considered positively by students. The students themselves determining the subject of the design sprint process and their role-playing an imaginary company are among the revisions made to the design sprint framework. In addition, rather than preparing visual materials for the jury and presentation, using these for testing the developed solution with potential users was a new approach, distinct from the conventional methods used in design education. The positive feedback of participant students emphasized the potential of the design sprint as a catalyst in

the project development process. However, further studies with varying sample groups are needed to verify the potential of the design sprint in design education. This study is carried out to find the effective and ineffective aspects of the application of the design sprint framework in design education. In that sense, the positive and powerful aspects of the design sprint in design education can be counted as challenging but productive nature of the rapid process, dealing with projects solely on work hours, continuous project development, diminishing the hierarchy in the design studio, and providing a chance for students to participate the whole process equally with other actors. In addition to that, the fast-paced essence of the design sprint framework might not always suit all cases in terms of creating testable physical prototypes and need for specialist's opinion and evaluation need to be considered.

It is inevitable for design education to have similarities with the new approaches in design practice because both evolved mutually. It is again inevitable for design education to remain close to other disciplines because their existences are dependent upon each other. In that sense, design sprint can serve as a connector between different disciplines in a new kind of design studio approach or it can be a tool to spread seeds of multidisciplinary work in the minds of students, or it can simply be a tool to accelerate the project process. So, depending on the context, different axes of the design sprint can be put forward in design education, being used within the frame of product focus, design management, business management or professional development. Finally, by benefiting from frameworks such as design sprint, it can be ensured that design education is kept up-to-date and the connection between design and other disciplines can be reinforced.

References

An Introduction to Design Thinking Process Guide (n.d.) https://dschool-old.stanford.edu/sandbox/groups/designresources/wiki/36873/attachments/74b3d/ModeGuideBOOTCAMP2010L.pdf Accessed 13 December 2019.

Banfield, R., Lombardo, C. T., & Wax, T. (2016). *Design Sprint: A Practical Guidebook for Building Great Digital Products*. O'Reilly Media, Inc.

Beckman, S. L., & Barry, M. (2007). Innovation as a learning process: Embedding design thinking. *California Management Review*, 50(1), 25–56.

Blank, S., & Dorf, B. (2012). *The Startup Owner's Manual: The Step-By-Step Guide for Building a Great Company*. California: K & S Ranch.

Brown, T. (2008). Design thinking. *Harvard Business Review*, June(6), 84–92. http://0-search.ebscohost.com.divit.library.itu.edu.tr/login.aspx?direct=true&db=edsggo&AN=edsgcl.179770754&lang=tr&site=eds-live Accessed 7 January 2020.

Cox, G. (2005). *Cox Review of Creativity in Business: Building on the UK's Strengths.* TSO.

Creswell, J. W. (2009). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*. Sage Publication.

Cross, N. (2001). Designerly ways of knowing: Design discipline versus design science, *Design Issues*, 17(1), 49-55.

Curedale, R. (2013). *Design Thinking Process and Methods Manual*. Topanga: Design Community College.

'Definition of industrial design' (2018). http://wdo.org/about/definition/ Accessed 19 November 2018.

Ferreira, V. G., & Canedo, E. D. (2019). Design Sprint in classroom: Exploring new active learning tools for project-based learning approach. *Journal of Ambient Intelligence and Humanized Computing*, 1, 22.

Figueiredo Correio, L. B., & Fleury, A. L. (2019). Design Sprint versus Design Thinking: A comparative analysis. *GEPROS*, 14(5), 23–47.

Fraser, H. M. A. (2009). Designing business: New models for success. *Design Management Review*, 20(2), 56–65.

Hassi, L., & Laakso, M. (2011). Design Thinking In The Management Discourse: Defining The Elements Of The Concept. *In 18th International Product Development Management Conference.*

Innovation by Design (2015). Design Council.

Johansson, U., & Woodilla, J. (2010). *How to Avoid Throwing the Baby Out with the Bath Water: An Ironic Perspective on Design Thinking,* Lisbon, Portugal: EGOS Colloquium.

Keijzer-Broers, W. J. W., & de Reuver, M. (2016). Applying agile design sprint methods in action design research: Prototyping a health and wellbeing platform. in *International Conference on Design Science Research in Information System and Technology*, 68–80.

Knapp, J., Zeratsky, J., & Kowitz, B. (2016). *Sprint: How to Solve Big Problems and Test New Ideas in Just Five Days.* Simon and Schuster.

Larusdottir, M., Roto, V., Stage, J., Lucero, A., & Šmorgun, I. (2019). Balance talking and doing! Using Google Design Sprint to enhance an intensive UCD course. In *IFIP Conference on Human-Computer Interaction,* Springer. 95-113.

Overbeeke, K., Appleby, R., Reinen, I. J. & Vinke, D. (2004). Nine competencies, six units: Industrial design education at TU/e. In *Proceedings of International Engineering and Product Design Education Conference*, Delft. 3-10.

Maurya, A. (2012). *Running Lean: Iterate from Plan A to a Plan that Works*, Sebastopol, CA: O'Reilly.

Melles, G. (2010). Curriculum design thinking: A new name for old ways of thinking and practice? In *Proceedings of the DTRS8 Conference, Sydney.* 299–308.

Mikkonen, J. (2013). The design sprint. In *IASDR 2013: 5th Intl Congress of the Intl Association of Societies of Design Research*. Tokyo: Shibaura Institute of Technology.

Mueller, R. M., & Thoring, K. (2012). Design Thinking Vs Lean Startup: A Comparison of Two User-driven Innovation Strategies. In *Proceedings of 2012 International Design Management Research Conference.* 151–161. https://doi.org/10.13140/2.1.1834.4647

Osterwalder, A., & Pigneur, Y. (2010). *Business Model Generation: A Handbook for Visionaries, Game Changers, and Challengers,* John Wiley & Sons.

Oxman, R. (1999). Educating the designerly thinker. *Design Studies*, 20(2), 105–122.

Raubenolt, A. (2016). An analysis of collaborative problem-solving mechanisms in sponsored projects: Applying the 5-day sprint model. *Journal of Research Administration*, 47(2), 94–111.

Ries, E. (2011). *The Lean Startup: How Today's Entrepreneurs Use Continuous Innovation to Create Radically Successful Businesses,* New York: Crown Business.

Sein, M. K., Henfridsson, O., Purao, S., Rossi, M., & Lindgren, R. (2011). Action design research. *MIS Quarterly*, 35(1), 37-56.

The Field Guide to Human-Centered Design (2015). Canada: IDEO.

Thomas, J., & Shin, S. S. (2016). Implementing design sprints in the education of industrial designers. *Design Principles and Practices*, 10(1), 59–73.

Walker, D. (1985). Writing and reflection, in D. Boud, R. Kneough and D. Walker (Eds), *Reflection: Turning Experience into Learning*, (pp.52-68), Oxon: Routledge.
Wrigley, C. & Straker, K. (2017). Design thinking pedagogy: The educational design ladder. *Innovations in Education and Teaching International*, 54(4), 374-385. doi:10.1080/14703297.2015.1108214
Yin, R. K. (2015). *Qualitative Research from Start to Finish*, Guilford Publications.

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26.2

Phenomenological Approach to Product Design Pedagogy: A Study on Students' Experiences in Interdisciplinary and Intercultural Settings

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Abstract
Product design pedagogical approaches require a specific mix of competences that demand multiplicity of perspectives, hybrid knowledge that exceeds professional field silos, and continuous problem reformulations. To do this, design studio education follows many traditions, among which is design critique. Design critique is believed to provide students with the ability to reframe design problems, but it can also lead to misunderstandings. The necessity of this approach is put into question by assessing the experiences of a group of students in an intensive course structured for interdisciplinary work, intercultural teams, and projects based on challenges from practice, where the critique was not part of the pedagogical program. The course was conducted over four consecutive weeks and supported a hands-on approach based on an interdisciplinary work between the areas of product design and occupational therapy, with the participation of Brazilian and Norwegian bachelor students and professors. Students responded to questionnaires prior to and at the end of the course that addressed their expectations of and experiences in the course. A qualitative analysis of the students' responses was carried out based on content analysis. The joint work with occupational therapy students and professionals, as well as the opportunity to develop projects that targeted demands from people with disabilities, were shown to be factors that contributed to students' engagement in the course and overall gain of knowledge. The experiences reported here indicate that the phenomenological approach to the design studio, which focuses on providing an immersive environment, deserves more attention from educators, and that design critique is not necessarily a crucial ingredient in design education.

Keywords
design studio critique, design pedagogy, interdisciplinarity, inclusive design, occupational therapy

Introduction
Product design education is grounded in practice rather than in theory. The design pedagogy theoretician Tovey noted that "there is a greater emphasis on being able to do it (design) than on designers being a repository of specialist knowledge." He further claimed that designers are "generalists in as wide range of content as possible" (2015, p. 37). Studying by exercising design allows for design process mastery that is then used to discover knowledge fields according to

Owen (2007). In his article about design thinking and its nature and use, he noted how design thinking is generalist in preparation and execution. Accordingly, he claimed that “the wider the reach of the knowledge base, the more likely the creative inspiration” (p. 24). This approach allows designers to address complex challenges that are multifactorial and global as well as work with dynamic problems that evolve as design projects develop (Rittel & Webber, 1974). The design discipline is therefore practical in the sense that it assumes processes of the accumulation of knowledge, development, and testing of concepts.

To teach this way of problem-solving, design pedagogy traditionally relies on practical projects and critiquing practice, which allows for the constant reframing of design problems and ideas. Critique is a common teaching process applied among participants in a design studio where the role of an educator is to both provide critique and teach fellow students to provide critique to each other, thus questioning their preferences and knowledge about the given problem (Gray, 2013). Critique is therefore done by all the participants, where criticizing each other’s approaches through the series of meetings is meant to facilitate critical thinking in the design studio. These pedagogical traditions rely on theories about critical reflection involved in the constructivist pedagogical approach (Schön, 2003), but also in critical dialectic approaches (Habermas, 1978), where students are supposed to incorporate multiple perspectives into their thinking and eventually into their designs.

Multiplicity of perspectives, hybrid knowledge that exceeds professional field silos, and continuous problem reformulations are, without a doubt, key ingredients of design discipline and good design pedagogy. However, the opinions on providing it by means of critique as a pedagogical tool have been at odds. While many understand this pedagogical practice as necessary (Kolko, 2011) and in need of theoretical formulation, others have questioned this practice (Goldschmidt et al., 2010). The criticism of design studio critique encompasses the issues of educators’ power over the students, especially as design methods are not scientific and rely on teachers’ professional design experience. This study questions the adequacy of critique as a pedagogical approach to state-of-the-art design studio education. We argue that immersive environments that provide immediate real-life feedback as well as meaningful human relations are the key factors of learning and will allow for multiple perspectives, interdisciplinarity, and the ability to reframe the problem. Even though constructivists themselves claim that experience and meaningful action are preconditions for critical reflection, we take the notion of immersive learning further and connect it to a phenomenological understanding of pedagogy.

Furthermore, the role of education should be to develop the knowledge, skills, attitudes, and values that enable people to contribute to an inclusive and sustainable future. Androutsos and Brinia (2019) argued that the current educational system needs to be changed because there is a gap between real-world needs and the current education methods. Education needs to prepare young people not only for the professional world, but also to give them the skills they need to become active, responsible, and engaged citizens (Organization for Economic Co-operation and Development, 2018). We see design immersive learning space as a part of the international effort to provide this kind of education.

Materials and Methods

Our phenomenological understanding of learning rests on ideas described by the phenomenologist Maurice Merleau-Ponty. Phenomenology explains learning as bodily situated and therefore happening in relation to the environment. Merleau-Ponty (1996, p. 164) explained that physical and social embodiment shapes meaningful learning. Embodied learning means that human bodily capacities, such as the mental, emotional, and physical, in relation to environmental affordances and constraints, are the preconditions for learning. The focus here is therefore on the relationship between the environment and learner and the connection they establish that changes them both. Accordingly, learning is a process in which previous knowledge allows participation in an embedded situation. Each additional act of learning modifies the entire horizon of experience and expertise. Learning means to change and transform oneself in relation to the environment. For phenomenologists, the object of scientific study to explain learning is therefore the relationship between the learner and the environment the learner inhabits. This is in contrast to constructivist ideas where learning is happening in learners' minds as a result of a construction of the model of the world they inhabit (Steffe & Gale, 1995).

Following Merleau-Ponty's ideas, we as educators facilitate a learning environment that will allow learners to establish relationships that will stimulate design learning. We create a learning environment based on three main pillars: 1) interculturality to stimulate multiplicity of perspectives, 2) interdisciplinarity to stimulate hybrid knowledge that exceeds professional field silos, and 3) real demand-based projects to stimulate continuous problem reformulations. This paper is based on assessing the perception of product design students about their educational experience in an international collaborative project in inclusive design, which involved design students from two universities, staff, and people with disabilities from a rehabilitation center. This immersive approach is closely connected to the inclusive design principles where empathy exercises, meeting users, and ownership of the project development are integral parts of the learning experience.

This unique research setting allows for studying immersive approaches for learners where they learn from their environment and relations that emerge as a result of the design activity. To assess this approach, we study students' expectations and experience/engagement in the course. Inclusive design is one of the approaches within the design area that is frequently associated with the theme of technologies for people with disabilities. Inclusive design emphasizes the need to understand customer diversity with the aim of better satisfying the needs of a wider range of people (Waller et al., 2015). It is therefore fertile ground for working across disciplines as it aggregates knowledge from the areas of rehabilitation applied to design practice. It is also a way to create an environment that demands design students to leave aside their own preferences and knowledge and put themselves in the position of patients and therapists.

By designing for people with disabilities, through collaborative work with rehabilitation professionals, students are provided a wider view of the user's need, thus contributing to ownership of the project briefing. Muller et al. (2019) found positive outcomes from a hands-on course on rehabilitation biomechanics for engineering students and observed that they developed an empathic client-centered design approach. Despite the growing number of studies reporting inclusive design experiences in education, there is still a lack of consensus

when it comes to the pedagogical approach. Indeed, a recent study (Wilson et al., 2019) found that there is a lack of clarity within inclusive design, with a wide variation in the methodologies taught.

Kiernan et al. (2020) highlighted the changes in design education toward collaborative work with other disciplines to address unstructured problems, which requires the designers to have skills to share information, negotiate, and reach consensus. Addressing current themes that are often complex, multifactorial, and of global interest is a means of stimulating interdisciplinary knowledge acquisition. Ramirez (2011) stated that there is an increasing involvement of the industrial design profession in themes of global concern and socially responsible design, and some design schools provide their students with the immersive experience in developing countries to learn collaborative design with local communities. In this context, Ferraelo (2019) emphasized that the practice of ethics and morality in design and engineering education can contribute to the development of an ethical industry that is able to address social issues.
Our academic experience reported here to some extent meets this current global educational context. Encouraging product design students to work with the demands from local communities, groups of social vulnerability, and people with disabilities is a means for the development of the sense of socially responsible design, thus contributing to the formation of engaged students.

Research design: Cross-sectional qualitative study

This study was carried out as part of the inclusive design course taught in 2019, which is part of the regular curriculum of product design at Sao Paulo State University (UNESP), Brazil. The 2019 course was held over 30 days from April 15th to May 13th, four days per week, and four hours daily.

Nineteen students (ten Brazilians and nine Norwegians) of the bachelor program in product design at UNESP and Oslo Metropolitan University (OsloMet) registered for this course. The course program was mostly practical and divided into four main blocks: (1) theoretical content on inclusive design, disabilities, and assistive and rehabilitation technologies, (2) practices of empathy development, methods of data collection, observation, and survey with people with disabilities, (3) meeting with real patients and assessment of their functional needs, preferences, and expectations, (4) project development, proposing solutions, and prototyping, and (5) prototype testing with the patients (Figure 1). The theoretical content, teaching methodology, and contact with students and professionals of occupational therapy and people with disabilities were clearly stated in the course description; thus, the enrollment in the course was by spontaneous demand. The pedagogical methods did not include critique from either peers or teachers.

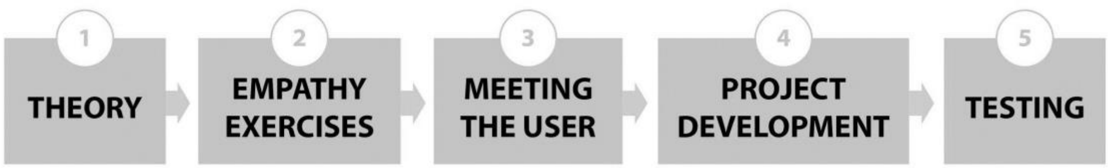

Figure 1. Course structure: From theory to prototype development.

A cross-sectional qualitative study was carried out at Bauru campus of the UNESP and in the Specialized Rehabilitation Center in UNESP-Marilla, a school clinic that provides rehabilitation services in the areas of physical therapy, speech therapy, and occupational therapy for people with disabilities, where design students had the opportunity to meet and work collaboratively with patients, occupational therapy students, and their supervisors.

The students worked in groups of approximately three members, and each group worked on a single case of a person undergoing a rehabilitation program at the Specialized Rehabilitation Center. Seven patients with neurological conditions participated in this course, including four children with cerebral palsy ranging in age from 3 to 9 years; one one-year-old child with brachial plexus injury; one five-year-old child with mild microcephaly; and one person 72 years old with Parkinson's disease. These patients were selected based on the therapists and caregivers' indications about the lack of products and technologies available that could facilitate the rehabilitation program and the performance of daily life activities.
Initially, the students received a summary of the patients' medical condition and rehabilitation program information, allowing them to gain knowledge about the patients' medical and functional status and help them prepare the interviews for the first meeting with the patient and therapist.

All the groups were allowed to follow one occupational therapy session of the patient with whom they were going to develop their project, and they were allowed to interview the therapist and the patient and/or the caregivers. From this first meeting, students then worked on defining the design goals and developed concepts of prototypes that could meet the rehabilitation goals as well as the patient's needs and preferences. After seven days, the students' groups met the occupational therapy team (professor and last year students) and presented their ideas and concepts and received feedback about the potential for success and possibilities of improving their design concepts. Finally, the students worked for seven days producing a prototype that was then tested by the therapist and patient during a rehabilitation session. This prototype test allowed the students to see their projects implemented in the rehabilitation routine and receive feedback from the occupational therapy team and from the patient or caregivers. During the entire design and prototyping process, students were supervised by design professors.

The non-probabilistic convenience sample consisted of nineteen (N = 19) students of the undergraduate course in design (11 Brazilians and 8 Norwegians), who enrolled in the course on personal demand.

For data collection, two questionnaires were applied: one before and the other after the course. The first questionnaire aimed to verify the students' expectations regarding the course, while the second was designed to assess their experience and engagement with the course. Both questionnaires contained open and closed questions and were constructed based on the literature. To verify the semantic adequacy and the adequacy of the questions in relation to the objective of the study, the questionnaires were submitted for analysis by two professors, one Brazilian and one Norwegian, both of whom are researchers who have worked with themes related to this study, who attested to the adequacy of the questionnaires.

Although a total of 19 students attended the course, the first assessment was answered by 15 students, while the second one was answered by 17 students. Seven Norwegian students answered both assessments, whereas eight Brazilian students answered the first application and 11 answered the second.

The data analysis was based on the content analysis proposed by Bardin (2011). From the careful reading of the participants' responses, the content was sorted and grouped according to similarity and relevance to the objective of this study. From this grouping, we arrived at the units of analysis, from which two categories emerged, namely "Expectations" and "Experience/Engagement," with their respective subcategories, according to their specific content, as shown in Figure 2. The category "Expectations" refers to the assessment prior to the course, while the Experience/Engagement refers to the assessment at the end of the course.

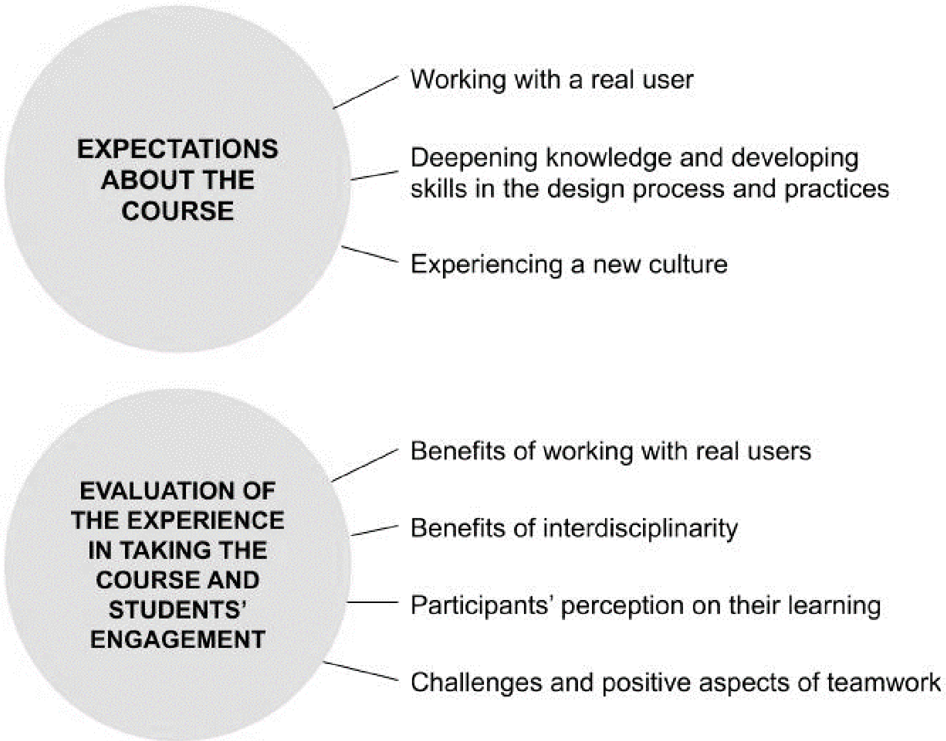

Figure 2. The two main categories with their supporting sub-categories.

Results

Results from the pre-course assessment are presented according to the respective category and subcategories, followed by the Experience/Engagement post-assessment and its subcategories.

Category 1 – Expectations about the Course

Prior to the beginning of classes, students were asked about their expectations when registering for the course. The main expectations identified were: (a) working with a real user (containing the terms real users, real patients, designing for/to, specific cases/conditions, purpose, real-life situations, disability, elderly, and assistive technology), (b) deepening knowledge and developing skills in the design process and practices (including terms such as inclusive design, methods, techniques, research methods, development as designer, CAD, and

3D printing), and (c) experiencing a new culture (including the terms experience, culture, different country/university/course, new approach, language, and communication).

Subcategory 1.1 – Working with a Real User

The opportunity to work with real users was an expectation when enrolling in this course for 46.7% of the students, especially due to the opportunity to develop products for people with disabilities or the elderly:

> *"[The most important reason why I registered for this course was] to develop skills in product design [and] to be involved with a real product for someone who needs it."*

> *"[The most important reason why I registered for this course was] to work with real users."*

Another expectation identified was related to socially responsible design. Students mentioned the opportunity to improve accessibility in a daily context as an expectation they had about the course:

> *"[The most important reason why I registered for this course was] to use design for a good purpose."*

> *"[At the end of the course, I expect to have learned] how to use design to help people live in a better and more inclusive society in this course."*

Subcategory 1.2 – Deepening Knowledge and Developing Skills in the Design Process and Practices

Eighty percent of the students showed interest in improving their knowledge and skills in design. The participants mentioned their expectations about developing skills in product design, including CAD and 3D printing, deepening their knowledge about inclusive design, and using this knowledge in the development of projects (from organization to a full project):

> *"[At the end of the course, I expect to have learned] new things about inclusive design as well as I expect I will find some directions toward which to go forward in my development as a designer."*

> *"I expect to learn how to organize and develop a project, mostly an inclusive project, considering the patients' needs."*

The opportunity to gain in-depth knowledge about inclusive design was mentioned by nine students. Deepening knowledge about the design process, methods, and research was another main expectation mentioned by six students:

> *"[At the end of the course, I expect to have learned] more about inclusive design, research methods, and different approaches."*

Subcategory 1.3 – Experiencing a New Culture
A total of 53.3% of the students reported their expectations about having new college and academic experiences:

> *"[The most important reason why I registered for this course] was to experience different ways of learning… and to experience how different a university is in another country."*

In addition, experiencing new cultures and becoming more comfortable in speaking and interacting in English, their non-native language, were themes mentioned by the students:

> *"[At the end of the course, I expect to have learned] . . . get out of the comfort zone and be more comfortable with the language."*
> *Collaboration with people from other countries was also a motivating factor to register in the course:*
>
> *"[At the end of the course, I expect to have learned] about Brazilian culture…and to collaborate with people from other countries"*

The differences in the design process and between academic life were pointed out by five students as a motivation for the course. A related topic – contact with a different culture – was also mentioned by four students. The last relevant topic was the improvement of communication and language skills, mentioned by three students.

Category 2 – Evaluation of the Experience in Taking the Course and Students' Engagement

At the end of the course, students were asked to evaluate their experience throughout the course regarding their learning outcomes and the positive and negative aspects they identified, and to give sincere feedback. Students pointed out the benefits of (a) working with real users and the (b) the interdisciplinary aspect of the course; (c) their perception of their learning regarding design process and practices, including the advantages and disadvantages of using digital modeling and manufacturing; and (d) the challenges and positive aspects of teamwork.

Subcategory 2.1 – Benefits of Working with Real Users
For most (94.1%) of the students, working with a real user was a very positive aspect about the course because it provided quick feedback, a better understanding of the user and their needs, and the development of empathy toward the user. Close contact with real users and their families was very helpful from both professional and social perspectives. From a professional point of view, working with real users helped the students to get relevant information to apply in their projects:

> *"[A positive thing experienced developing projects for real patients was the] importance of understanding individual human needs."*
>
> *"It's nice as a designer to know that someone is going to use the prototype, and the challenge prepared us for the 'professional' life."*

From the social point of view, it created empathy, which helped them to put themselves in the "other person's shoes":

> *"[The most important thing I have learned in this course was] to work with real-life situations, and to be in another person 'shoes.'"*

> *"[The most important thing I have learned in this course was] empathy, putting yourself in other people's shoes is a basic part of the project."*

The user's involvement also influences the development of students' projects since it creates a higher motivation in developing a product and higher engagement in meeting and satisfying the user's needs:

> *"It was very positive to develop for real people, mostly because of the gratification that you feel when you see it working, [sic] other good thing was how easy we could obtain information and feedback."*

In the end, some students pointed out that working with real users improved their confidence in developing an inclusive design project:

> *"I feel a little confident because now I feel I can communicate with patients/families well enough to bring something to the project."*

Subcategory 2.2 – Benefits of Interdisciplinary Work

Working with professionals from other areas, namely occupational therapy, was also a positive experience highlighted by the students. They mentioned that working with the rehabilitation center, alongside the occupational therapists, helped to meet their expectations for the course. The majority, 82.4% of the students, stated that having the professionals was very important in the mediation with the patient and that it helped them to better understand the users' specificities and needs as well as offering another point of view:

> *"It was very good to be able to have this contact with people with greater knowledge in the area [occupational therapy] for better direction and to have another point of view."*

> *"I think this interdisciplinarity is very cool, and I was able to get to know more about occupational therapy."*

> *"[A positive thing experienced collaborating with the occupational therapists was] having a professional (therapist) to guide our decision-making."*

Subcategory 2.3 – Participants' Perception of Their Learning

Another positive outcome from the course was the perception of improvement in the students' knowledge and skills. Several students expressed feeling more confident in developing a project – from concept to prototype – especially an inclusive design project, because they felt they had learned about the process:

> *"Now, I am able to understand what it takes to go through all the process, [sic] since meeting the patient until delivering the prototype."*
>
> *"How to make something from scratch in a short period of time because we had little time and very real expectations to meet, so it had to be done."*
>
> *"I feel confident because I had a good experience when learning many aspects at prototyping accessible inclusive design projects."*

Students also mentioned having both positive and negative experiences with digital modelling and manufacturing. On the positive side, for 76.5% of the students, working with digital modelling and manufacturing was an advantage because it helped to visualize an idea, identify failures in the project, and make changes, as mentioned by one of the students: "[Working with digital modelling and manufacturing was] a good way to visualize your product/prototype from different views and easy to change dimensions and colors."

When answering what had the greatest impact on learning student responded:

> *"Actually delivering a product that may have an impact."*

On the other hand, for 58.8% of the students, it also provoked negative experiences because some students felt they did not have enough knowledge or skills to work with it. They pointed out the lack of experience with these technologies as too challenging to solve in the short time given to deliver the prototype:

> "Digital modeling (to use milling machine and 3D printing) provides us many possibilities. But not everybody was prepared to do it."

Subcategory 2.4 – Challenges and Positive Aspects of Teamwork

Working in a team created both friendly and challenging experiences. A total of 64.7% of the students mentioned that communication was challenging several times, and 23.5% noted that they did not feel very comfortable with their English skills. On the other hand, although communication was difficult, they seemed to have overcome it with the help of their classmates, as observed by one student:

> *"The only thing that demotivated me was the language because I could not express my ideas totally, but my classmates helped me a lot in this matter."*

Overall, working with people from different cultures was seen as a motivating and positive experience:

> *"[The most important thing I have learned in this course was] collaborations with different people from different cultures because collaborations can happen beyond language, through drawings, modeling, and visual communication."*

"I was hoping to get to know people with a completely different way of life, vision of things . . . and it was awesome because all of these [sic] contact really made me grow as a person and as a designer."

Other situations that were experienced and overcome within the teamwork were the opportunity for improvement and learning:

"[The most important thing I have learned in this course was] to be a little more patient and understanding that for a project to happen, sometimes we must share tasks and understand that each person can contribute in some way. And friends, regardless of how little time, I feel I have new friends."

Discussion

Analyzing the interviews, we can see how the relational approach to learning played out through this study. Students described their learning in relation to patients, therapists, prototyping technology, design media, and their colleagues from other universities. Their knowledge was situated and arose from the learning setting. Even when they were asked to assess their own learning, their descriptions included design medium/3D printing technology and practical aspects of the use of it for users' benefits. Many of them had a steep curve learning in terms of 3D modeling, engineering, and ergonomics at the same time. Still, it was meaningful because of the patient care and immediate feedback.

A teaching approach of inclusive design based on cross-disciplinary work and project development for real users was shown to benefit students' engagement with the course, confidence, and ability to gain knowledge. Positive reports mainly related to the opportunity to meet and work with people with disabilities and occupational therapy students and their supervisors.

Occupational therapists played an important role in collaborative work by contributing to the definition of the main project requirements as well as the most appropriate features and functions of a given assistive device that could better meet the users' needs. The knowledge from the occupational therapists' practice was essential for the design conceptualization of an assistive device in addition to the designer's expertise (Moraiti et al., 2015). Indeed, our experience in this course showed that the participation of the occupational therapy team provided an important contribution supporting the design students in making key decisions in the design process. This finding is supported by the feedback from the therapists and the users' family/caregivers about the students' projects during the prototypes' final tests with the users. They reported that, in general, although improvements could and, in some cases, needed to be implemented, taking into account the fact that it was a first prototype test with the user, the prototypes had design features that were in accordance with the users' capabilities, needs, and rehabilitation goals as well as to their preferences.

Although there is a body of knowledge that is specific to the rehabilitation sciences, design students were able to comprehend the main aspects related to the disability and functioning of each patient and, based on this, to propose solutions that could meet their needs, preferences, and expectations. We believe that project development based on real users' demands was a key factor that facilitated the gain of interdisciplinary knowledge. Corroborating with this, the

study of Self et al. (2019) found that students responded positively to interdisciplinarity when it could be applied to their projects.

Working with actual users and developing a complete project – from concept to prototype – was considered the main motivation for the students to enroll in this course and, at the same time, a positive factor that met their expectations. Most of the students mentioned this opportunity as a highlight of the course because working with the user, as well as in collaboration with the rehabilitation center, was considered helpful in the learning process. Our results indicate that a more practical course can stimulate students' engagement and benefit the learning process. In agreement with our findings, Self et al. (2019) observed that direct application of learning is an important element for gaining interdisciplinary knowledge. Interdisciplinarity provided students a broader perspective on the design problems, with consequent interlocution among professionals from different areas and spaces of shared decisions, aiming at the integral attention to the subjects with disabilities. Additionally, the study of Androutsos and Brinia (2019) found that the use of a co-design process methodology, that is, the collaboration with real users and other members (in this case the occupational therapists) in educational practices, leads students to be more creative and innovative.

The students' reports of concern about delivering their projects to a real user might be interpreted as a sense of responsibility with their work that was brought about by the development of empathy with the user. This is in accordance with the findings of Muller et al. (2019), who reported the development of an empathic user-centered approach in engineering students who attended a hands-on course on rehabilitation biomechanics. Perhaps this kind of educational setup and real-life feedback were more motivating than seeking consensus about what is a good design by teachers and peers through a design critique. In this study, this was especially visible as students gave positive course evaluations even though their grades were not markedly better than in other courses. Additionally, some of the designs students proposed throughout the course did not achieve the desired reactions by the patients, which students themselves have acknowledged and commented on, showing the ability to be self-critical.

We noted the students to be engaged in designing solutions that could be useful and helpful for the patient, and this feeling of responsibility, empathy, and willingness to help someone was triggered after the first meeting with the patients. Such observations suggest that the course strategies contributed to the development of positive social attitudes by the students. Social attitudes are part of a dynamic process that incorporates human relations as generators of novel perceptions, meanings, and attitudes toward a social object or actors, in this case, the people with disabilities. Ferraello (2019) highlighted the importance of implementing practices of ethics and morality in educational approaches to design and engineering. The experience of being in contact with people with disabilities supports the development of favorable attitudes in relation to them and, consequently, empathic behavior and the willingness to establish social interactions and help them (Baleotti, 2006). The course format reported here, based on interdisciplinarity, interculturality, and real demand projects, was effective in developing a user-centered practice and had a positive impact on students' engagement and learning. It also supported the presumption that the learning and self-awareness of students comes from real experience, rather than only being construed in their minds through critique by their peers and educators.

Conclusion

This paper reported the outcomes of the students' experience of and perceptions about an approach to inclusive design teaching based on interdisciplinarity and interculturality. This teaching strategy was shown to greatly benefit students' learning and engagement with the course. The opportunity to develop projects for real users and the cross-disciplinary work with occupational therapy students and professionals were the most positive outcomes reported by design students. They were able to engage in an experience that provided a basis for gaining knowledge and developing skills of group work (communication, sharing, decision-making), improved their confidence in developing projects, and, finally, enhanced their development of empathy. The possibility of evaluating a teaching approach in which the student assumes the role of protagonist, interacting with the person with a disability and with health professionals, is a relevant element in the development of skills of collaborative interdisciplinary work as well as the search for sources to expand the discussion on the subject. To be part of these sources is what is expected with the realization of this research, obviously, without the intention of being the final word on the subject, but of offering a contribution to the discussion, especially in the scope of the teaching methodologies of inclusive design.

The study therefore indicates the feasibility of the phenomenological pedagogical approaches in design studio, which puts into focus the affordances and constraints of the design environment, rather than construction of knowledge by critical reflection. Consequently, it shows that good learning outcomes can be achieved without the critique approach to design learning. In fact, the study shows that critique can be replaced by a stimulating learning environment where design challenges come from the reality where the mistakes are explicitly uncovered *in situ* with patients and therapists, rather than simulated by previous experience of the educator and theoretical discussions by peers. Therefore, it is important for design to explore beyond the field silos and become familiar with enabling knowledge creation by means of integrative and collaborative interdisciplinary work where real-life feedback is imperative in an externally interconnected design studio.

The global challenges of modern life require a new approach to education. In this context, in areas such as product design that have a strong connection with technology and people, knowledge must be built on the foundations of interdisciplinarity, interculturality, and the ability of students to exercise agency over the design situation.

Constructivist pedagogy has brought into focus student-centered education. In this pedagogical approach, minimal influence of educators and safe space for social development are considered to be central topics. The phenomenological approach to learning in design studio takes this topic further. In this approach, educators are important as organizers of rich learning environments and supporters of students' agency in these environments. This article shows that pedagogues should perhaps focus more on learner immersion rather than on the content of the curricula or academic discussions.

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References

Androutsos, A., & Brinia, V. (2019). Developing and piloting a pedagogy for teaching innovation, collaboration, and co-creation in secondary education based on design thinking, digital transformation, and entrepreneurship. *Education Sciences*, *9*(2), 113. doi:10.3390/educsci9020113

Baleotti, L. R. (2006). *Um Estudo do ambiente educacional inclusivo: descrição das atitudes sociais em relação à inclusão e das relações interpessoais* [Doctoral dissertation, São Paulo State University].

Bardin, L. (2011). *Análise de conteúdo [Content Analysis]*. Edições 70.

Ferraello, L. (2019, September 12–13). Social awareness in design & engineer education and practice. The value of ethics in postgraduate education. In E. Bohemia, A. Kovacevic, L. Buck, R. Brisco, D. Evans, H. Grierson, W. Ion, & R. I. Whitfield (Eds.), *Towards a new innovation landscape*. Proceedings of the 21st International Conference on Engineering and Product Design Education (E&PDE 2019), The Design Society, University of Strathclyde, Glasgow. https://researchonline.rca.ac.uk/3930/

Goldschmidt, G., Hochman, H., & Dafni, I. (2010). The design studio "crit": Teacher–student communication. *AI EDAM, 24*(3), 285–302.

Gray, C. M. (2013). Informal peer critique and the negotiation of habitus in a design studio. *Art, Design & Communication in Higher Education*, *12*(2), 195–209. doi:/10.1386/adch.12.2.195_1

Habermas, J. (1978). *Knowledge and human interests*. Heinemann.

Kiernan, L., Ledwith, A., & Lynch, R. (2020). Comparing the dialogue of experts and novices in interdisciplinary teams to inform design education. *International Journal of Technology and Design Education,* 30, 187–206. doi:10.1007/s10798-019-09495-8

Kolko, J. (2011). Endless nights---learning from design studio critique. *Interactions, 18*(2), 80–81.

Merleau-Ponty, M. (1996). *Phenomenology of perception*. Motilal Banarsidass Publisher.

Moraiti, A., Abeele, V. V., Vanroye, E., & Geurts, L. (2015, January 15–19). Empowering occupational therapists with a DIY-toolkit for smart soft objects. In B. Verplank & W. Ju (Chairs), Proceedings of the Ninth International Conference on Tangible, Embedded, and Embodied Interaction (TEI '14) (pp. 387–394). ACM Press. https://dl.acm.org/doi/10.1145/2677199.2680598

Muller, O., Dangur, V., & Benyamin, B. (2019). Developing devices for people with disabilities: Challenges and gains of project-based service learning. *The International Journal of Engineering Education*, *35*(5), 1402–1414.

Organization for Economic Co-operation and Development. (2018). *Future of Education and Skills, Education 2030.* https://www.oecd.org/education/2030/E2030%20Position%20Paper%20(05.04.2018).pdf

Owen, C. (2007). Design thinking: Notes on its nature and use. *Design Research Quarterly, 2*(1), 16–27.

Ramirez Jr., M. (2011, August 15–18). Designing with a social conscience: An emerging area in industrial design education and practice. In S. J. Culley, B. J. Hicks, T. C. McAloone, T. J. Howard, & J. Malmqvist (Eds.), *Impacting society through engineering design*. Proceedings of the 18th International Conference on Engineering Design (ICED 11). The Design Society, The Technical University of Denmark (DTU), Copenhagen. http://www.designsociety.org/books_and_proceedings.htm

Rittel, H., & Webber, M. (1974). Wicked problems. *Man-made Futures, 26*(1), 272–280.

Schön, D. (2003). *The reflective practitioner: How professionals think in action.* Arena.

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*, 843–876. doi:10.1007/s10798-018-9460-5

Steffe, L. P., & Gale, J. E. (1995). *Constructivism in education*. Psychology Press.

Tovey, M. M. (2015). *Design pedagogy: Developments in art and design education*. Ashgate Publishing, Ltd.

United Nations. (2020). *Sustainable development goals*. https://www.un.org/sustainabledevelopment/sustainable-development-goals/

Waller, S., Bradley, M., Hosking, I., & Clarkson, J. (2015). Making the case for inclusive design. *Applied Ergonomics*, *46*, 297–303. doi:10.1016/j.apergo.2013.03.012

Wilson, N., Thomson, A., Thomson, A., & Holliman, A. F. (2019, August 15–19). Understanding inclusive design education. In S. Wartzack, B. Schleich (Eds.), *Responsible design for our future*. Proceedings of the 22nd International Conference on Engineering Design (ICED19) (pp. 619–628). The Design Society, University of Strathclyde, Glascow. https://doi.org/10.1017/dsi.2019.66

World Health Organization. (2018). *Assistive Technology*. https://www.who.int/news-room/fact-sheets/detail/assistive-technology

Book Review

The Impact of Technology Education: International Insights

De Vries, M. J., Fletcher, S., Kruse, S., Labudde, P., Lang, M., Mammes, I., Max, C., Münk, D., Nicholl, B., Strobel, J., & Winterbottom, M. (Eds.) (2020). The Impact of Technology Education: International Insights. Münster & New York: Waxmann.

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Reviewed by Jonas Hallström, Linköping University, Sweden

Introduction

The edited book *The Impact of Technology Education: International Insights* was published by Waxmann on behalf of the Center of Excellence for Technology Education (CETE), which operates out of the University of Duisburg-Essen, Germany. The book includes nine chapters covering a diversity of topics and methods, ranging from quantitative studies of technological self-efficacy, technological literacy, and digital competencies to qualitative studies of the significance of gaming for decision-making capabilities, the importance of tinkering and making for technology education, and national evaluations of technology education. *The Impact of Technology Education* is thus a multi-faceted book which is also truly international with altogether eleven editors. It includes researchers and contributions from Germany, Switzerland, Luxembourg, the Netherlands, the UK, and the USA, but the majority of chapters deal with research made in and about the German-speaking countries.

Overview of chapters and themes

The book begins with a short preface that introduces the main, overarching theme of the book – the impact of technology education – as well as including a brief overview of the chapters of the book.

The first chapter is entitled “Primary-school pupils’ self-efficacy and its influence on solving technological problem-based design tasks” and was written by Victoria Adenstedt and Annika Gooβ. They set out to present two works in progress and the first results of these studies. The authors re-introduce the concept of *technological self-efficacy* from McDonald and Siegall (1992) to denote pupils’ self-efficacy concerning technological tasks in particular. There are two different aims of the chapter, one for each of the two ongoing studies: 1. to investigate the technological self-efficacy beliefs of primary-school pupils; and 2. to determine whether differences in the solving of a technological problem-based design task between pupils exist, and whether one can detect an influence of self-efficacy and previously gained experiences. Gender perspectives are also important features of the two studies.

Although the second study is really only partially reported and thus inconclusive, the results indicate that nine-year-olds show above-average technological self-efficacy expectations, especially among boys. At the same time, in the problem-solving task a slight majority of the pupils rely on assistance from the teacher rather than trust their own capabilities, which might be interpreted as indicating a less prominent technological self-efficacy.

The second chapter of the book was written by Stefan Fletcher and is entitled "What distinguishes a technology literate pupil? Conception and development of a test instrument". Technological literacy and related concepts like technological capability and technological competence feature a great deal in connection with the development of curricula and standards in design and technology education (e.g. Doyle, Seery, & Gumaelius, 2019). However, little is known about the actual technological literacy of pupils, probably because it is still a vague and amorphous concept. Fletcher's chapter thus reports on the construction and validation of a test instrument for measuring the technological literacy of pupils. It is by no means a small venture and thus this research was initiated by the Center of Excellence for Technology Education, and also includes the University of Delft, the University of Luxembourg, the University of Education Schwäbisch Gmünd, and the University of Applied Sciences and Arts Northwestern Switzerland.

The chapter involves the definition of technology and technological literacy, with the following characterization of technological literacy: "The ability and willingness, on the basis of technology-oriented concept, everyday related and evaluation knowledge, to successfully execute typical technical forms of actions in different application contexts and to be able to estimate the consequences for themselves and for society" (p. 35). It should be noted that this definition was not based on any technological or philosophical literature. However, the succeeding design of the test instrument and the included types of technology used for testing technological literacy of pupils, were thoroughly informed by the analytical philosopher of technology Günter Ropohl (e.g. Ropohl, 1979). The resulting test items and task format are described, as are the results of the performed trials of the content validity of the questionnaire.

Chapter three is called "Affinity for technology of girls and boys of lower secondary school level", and was written by Karin Güdel, Anni Heitzmann and Andreas Müller. It investigates the effects of an intervention on the affective and cognitive variables of pupils' "Affinity for Technology" (AFT), conceptions of technology and technical/technological competencies. The intervention is of the classical kind with experimental group and control group. The AFT of the pupils in the experimental group is investigated through the lens of general acceptance of technology (attitude), individual interest, self-efficacy in solving technical tasks (a kind of technological self-efficacy, see above), and career aspirations, in several different contexts.

The conclusions of this chapter are manifold. The general attitude toward technology of most grade 7 and grade 8 pupils in the study is more positive than when technology is related to specific contexts. The authors conclude: "Hence, interest in technology drops with an increasing specificity of the context" (p. 54). Regarding gender, girls' perceived self-efficacy is lower than boys' in most technical activities, except for when planning and designing where they exhibit the same level as boys. Regarding the effects of the intervention, 75% of the pupils liked the technology class regardless of gender. The AFT was also lower in grade 9 than in grade 7, regardless of gender and whether one was part of the experimental group or the control group.

Christian K. Karl and Heide Lukosch wrote the fourth chapter, entitled “Increasing decision making competencies by applying simulation and gaming in technology and engineering education”. It deals with two game interventions and how they affect engineering students’ decision-making capabilities, in a German higher education setting. The intervention involves both a regular board game designed to include decision-making alternatives (Decision Areas, DA) for a construction contractor in procurement activities, and a virtual game involving technology-related problem-solving and decision making.

The authors conclude that students can learn about decision making in a lucid setting through game interventions, not only by playing but also by designing such games. They offer some implications for how to design successful games for technology and engineering education, based on, among other things, decision-making theory. One final remark is that there is evidence that online, database-driven games may have promising affordances and could play an even more vital role in teaching and learning in blended scenarios, that is, where real-life and virtual learning contexts are mixed.

The fifth chapter was written by Stefan Kruse and Alexander Franz Koch and is entitled “Competences in a digitalised world in the context of general and vocational technical education and training”. The chapter is based on a larger, previous Swiss study but here applied to a German context. Thus, in the current chapter there is a secondary analysis of a quantitative Delphi study performed with German experts in relation to the German VDI technical competence grid (VDI is the Association of German Engineers). The participating experts were professional engineers, VET (Vocational Education and Training) practitioners in engineering, and school teachers in technology, and they rated the educational relevance for the transition from school to VET or university, and the overall future potential, of three central technological domains: internet of things (“smart” networked artefacts), cyber-physical systems (e.g. navigation systems), and socio-technical systems (in this context, human – machine/computer systems). The central problematic was thus how well standards meet transitional requirements.

The results of the study show that there was generally a high degree of agreement among the experts, but the VET practitioners rated items slightly lower than the other groups. Furthermore, the domain internet of things was considered the most relevant content area in terms of transition to vocational training, but not to university. The internet of things was thus seen as more practically oriented than, for instance, socio-technical systems, which were regarded as more geared toward higher education. However, the experts did not agree regarding the relevance of socio-technical systems for VET.

Chapter six, “Technology education in pre-school and primary school” by Ingelore Mammes, deals with the inclusion of technology education in early education, that is, pre-school education and primary education, in Germany. The chapter includes a qualitative analysis of technology in pre-school and primary education curricula, which generally do not feature a subject called “technology”, in 14 German federal states. The findings of the study presented in this chapter show that almost all federal states include technological content in their curricula for social studies and science, although it is not labeled as technology but is submerged under other headings. More concrete content – such as everyday and playground equipment, model making, stability and bridges, the proper handling of tools, machinery and equipment, and

materials – are featured in most states' curricula. Mammes concludes that although the situation regarding technology in early education has greatly improved in recent years, it still needs to be further developed.

Chapter seven, entitled "Tinkering *with* technology education" and written by Elizabeth McGregor Jacobides and Mark Winterbottom, provides an argument for the inclusion of tinkering and making in technology and engineering education. The theoretical basis can, according to the authors, be found in Jean Piaget's constructivism and Seymour Papert's constructionism, but they also bring in several other frameworks and theoretical insights. Although the chapter really is about tinkering, there is also a great deal of reference to making as its mirror image, because making is what is going on in technology and engineering education a great deal. However, the authors point to the fact that "Making emphasises *product*, Tinkering emphasises *process*" (p. 119).

In this regard, the chapter makes the point that tinkering could really infuse engineering and technology education as a space in between self-directed and supervised learning. In particular the chapter makes the argument that the engineering design process shares many similarities with tinkering, and proposes a model that includes both engineering and tinkering in seven related areas: Pupils are engaged in purposeful, practical problem-solving; pupils take ownership of the design and make process; pupils embrace and learn from failure; pupils' curiosity and creativity are responded to; pupils demonstrate mastery from other curriculum areas (most notably STEM, according to the literature they build the model upon); pupils draw on a range of thinking skills and personal capabilities; and pupils' learning experiences are guided by a whole-school approach (p. 134).

The eighth chapter in this volume, "Current state and suggestions for the K-12 STEM school industry partnership in the United States" by Johannes Strobel and Yan Sun, takes as its starting point efforts in the USA to improve STEM education in schools by forming partnerships with various societal actors. More specifically, the authors designed a taxonomy of K-12 STEM school-industry partnerships, after examining 72 such cases through a literature review. The taxonomy consists of focus discipline (integrated STEM, or individual STEM disciplines), target audience/school level, role of school, role of industry, and role of third partner which could be, for example, any level of government, teachers' associations, or higher education institutions.

Based on the taxonomy, a model is also proposed for building effective K-12 STEM school-industry partnerships. The model focuses on optimizing such school-industry relationships so that it is possible to utilize the strengths of both parties, with help from third parties such as colleges or universities. The authors also issue some recommendations for successful partnerships: 1. Commitment from school partners is necessary to make the programs work; 2. There is a difference between a donation and a partnership, which must be understood to be able to make a difference in the partnership programs; 3. The programs should focus on research-based STEM education curricula with proven track records; 4. More programs should focus on underserved and underrepresented talent pools; and 5. Efforts should be made to create programs to capture pupils' interest in STEM at an early age (p. 157).

Chapter nine is entitled "National evaluations of technology education: what do they tell us about the impact" and was written by Marc J. de Vries. The author takes up the introduction of

technology education as a separate subject in many countries in the 1980s and 1990s, and subsequent efforts to follow up this introduction by way of national evaluations. The chapter deals with two national examples, one national evaluation in the Netherlands in the late 1990s, and one evaluation in England in 2007-2010. The aim of the chapter is to describe and discuss the nature and outcomes of these two national evaluations, and to investigate to what extent it is possible to establish whether the promises made when introducing technology education were actually met.

The author shows that there were many similarities between the two national evaluations, for instance, the ways they were performed through school inspections. Furthermore, the state of the subjects Technology and Design and Technology respectively was quite similar in that in weak schools' technology teachers were isolated and only implemented parts of the curriculum. As regards differences, in the Netherlands the focus was very much on making skills, but without the design element, whereas in England the focus was on design that also included the making of a product. Pupils were also more positive about the subject in England than in the Netherlands. It must be emphasized here that these are two historical evaluations that do not necessarily reflect the situation today, although a lot still seems to be the same as de Vries points out.

Conclusion – weaknesses and strengths

Regarding weaknesses, the book's theme of the "impact" of technology education is vague and could mean a number of things. In the preface, it is defined as "the impact it has on the personality development in technology" (p. 8), and this definition might include some of the first chapters. The final chapter by de Vries also relates to the impact of technology education, but on a more general level in relation to national educational evaluations. This was really what I first expected when I read the title. A more comprehensive theme could have made the title more inclusive of the variety of studies in the volume. Another weakness is that the book includes several ongoing studies which have inconclusive findings. Finally, I miss a more thorough critical perspective on technology and technology education, for instance, in relation to the issue of impact. It could be anything from the importance of critiquing when designing in order to make products more sustainable (e.g. Williams & Stables, 2017) to including in technology teaching discussions of the implications of technology development for a future society, for example, the impact of artificial intelligence and human-machine systems on job opportunities (e.g. Hallström, 2019).

However, in terms of the strengths of the book, some such critical perspectives do feature in certain chapters. Chapter two deals with the issue of evaluation of technology as a feature of technological literacy, and chapter five discusses the possible future effects of socio-technical systems/human-machine systems on the job market. De Vries, finally, connects the theme of impact to a critical perspective when he claims that "the whole idea of having technology in schools is in the factual social impact ON technology and the desired social impact OF technology" p. (172).

Another strength that applies to the whole book is that *The Impact of Technology Education* offers a comprehensive compilation of technology education studies from primarily German-speaking European countries, which is very much needed. Researchers from, for example, Germany and Switzerland do not publish in international English-language journals such as the

International Journal of Technology and Design Education or *Design and Technology Education: An International Journal* to the same extent as researchers from the USA, the UK, Australia, New Zealand, Western and Northern Europe (e.g. Xu, Williams, Gu, & Zhang, 2020). It is evident from this book that a great deal of highly relevant and novel technology education research is produced in German-speaking countries and therefore never reaches an international audience. One can only hope, for example, that the actual, future findings of the promising international investigation of pupils' technological literacy in Chapter two will be published in an English-language journal or book (chapter). The fact that *The Impact of Technology Education* includes such international studies that also connect German-speaking researchers with the American, British, and Dutch research community only adds to the value of the book and its contributions.

In particular, I want to commend the studies in the beginning of the book dealing with pupils' attitudes to technology (education), and attempts made in these studies to measure pupils' technological literacy and technological self-efficacy, in relation to central issues such as gender. The chapters on digital competencies in vocational education, tinkering/making and early childhood education are also highly relevant and much needed to develop the field of technology education as well as teaching in schools.

References

Doyle, A., Seery, N., & Gumaelius, L. (2019). Operationalising pedagogical content knowledge research in technology education: Considerations for methodological approaches to exploring enacted practice. *British Educational Research Journal*, *45*(4), 755-769.

Hallström, J. (2019). Clive Staples Lewis: Social, Environmental and Biomedical Implications of Technology. In J.R. Dakers, J. Hallström & M.J. de Vries (Eds.), *Reflections on Technology for Educational Practitioners: Philosophers of Technology Inspiring Technology Education.* Leiden & Boston, MA: Brill Sense.

McDonald, T., & Siegall, M. (1992). The effects of technological self-efficacy and job focus on job performance, attitudes and withdrawal behaviors. *The Journal of Psychology, 126*(5), 465-475.

Ropohl, G. (1979). *Eine Systemtheorie der Technik*. Munich: Carl Hanser Verlag.

Williams, P.J., & Stables, K. (Eds.) (2017). *Critique in Design and Technology Education*. Singapore: Springer Nature.

Xu, M., Williams, P.J., Gu, J., & Zhang, H. (2020). Hotspots and trends of technology education in the International Journal of Technology and Design Education: 2000–2018. *International Journal of Technology and Design Education, 30*, 207–224.