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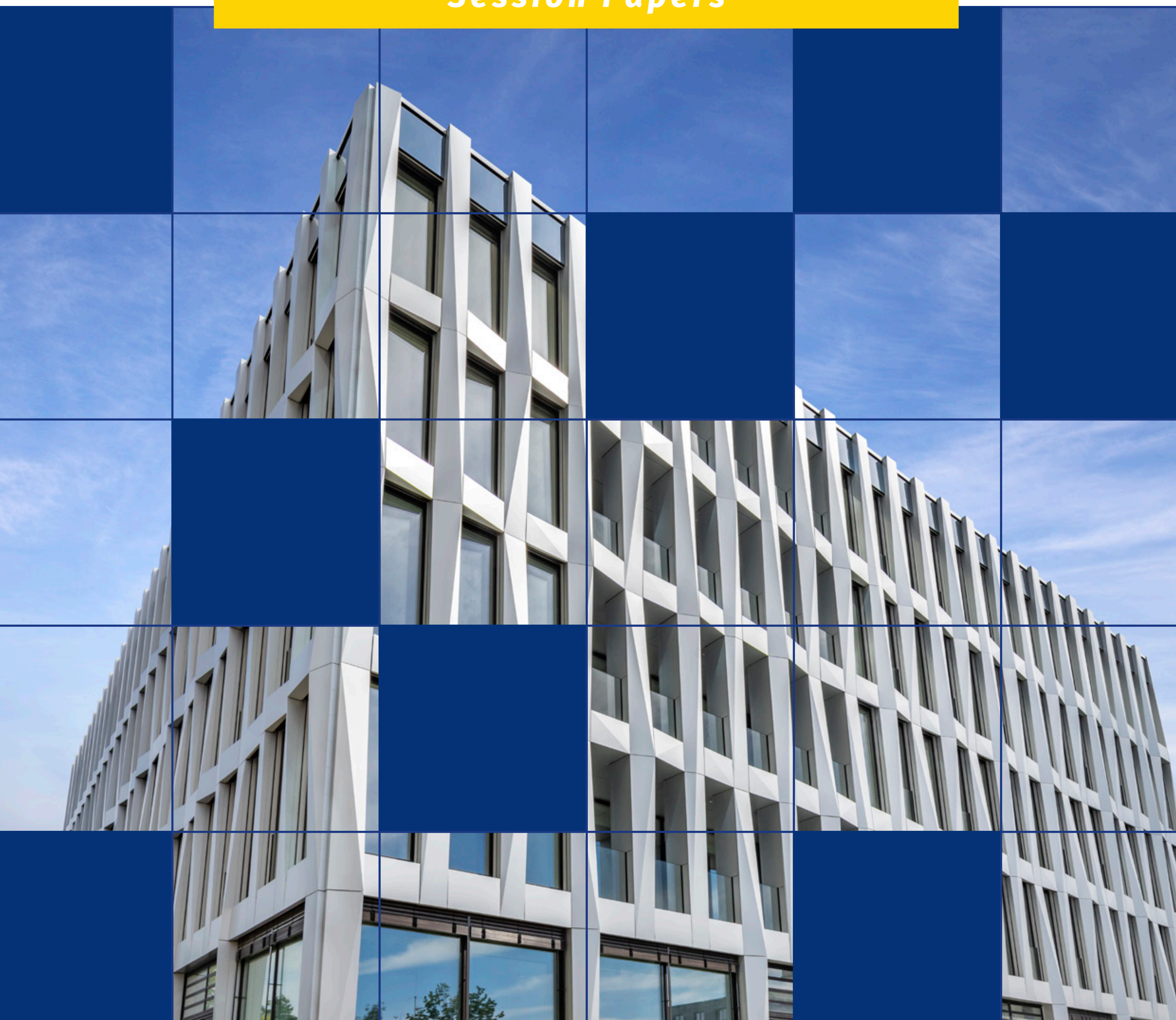
Session Papers



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INHALT

GLOBAL PARTNER EUROPEAN ALLIANCE

In 2017, six universities came together to develop relationships and strategic collaborative opportunities through successful development and delivery of university level degree programs, applied research, professional development programs, and community outreach activities.

THE CURRENT MEMBERS ARE:

Coventry University, Coventry, United Kingdom
Darmstadt University of Applied Sciences, Darmstadt,
Germany Technological University Dublin, Ireland
Lucerne University of Applied Sciences, Lucerne, Switzerland
Purdue University, Indiana, USA
University of Wisconsin – Stout, Wisconsin, USA

Each of these members brings unique strengths to the overall membership in creating an alliance addressing increased effectiveness, professionalism, and performance of our institutions while promoting broad and positive economic impact. Additional Alliance members will be recruited as and when additional initiatives and target activities are identified. The recruitment of additional members requires the mutual agreement of two-thirds of the founding members. We are currently in discussions with several candidate member institutions.

POLYTECHNIC SUMMIT

Among the scope of activities set out in the GPEA charter, e.g. a regular summer school, is the hosting of an annual conference – the Polytechnic Summit. Most recently this summit was hosted in the following years and locations:

+ 2017 – Purdue University, Indiana, USA
+ 2018 – University of Engineering and Technology, Lima, Peru
+ 2019 – University of Wisconsin-Stout, Wisconsin, USA
+ 2021 – Technological University Dublin, Ireland (hosted virtually)
+ 2022 – Darmstadt University of Applied Sciences, Germany
+ 2023 – Utah Tech University, Utah, USA (planned)

POLYTECHNIC SUMMIT 2022 THEMES

DESIGN (PROGRAMMES, CURRICULUM, ORGANISATION)

Under this theme, PS2022 will explore the concept of design – looking at how the university itself can be designed, how the curriculum can be designed, and the programs within that curriculum. Speakers will address the challenges of creating a new university in different parts of the world. They will also explore the no-less-challenging aspect of developing or innovating a connected curriculum that contains core elements that define the identity of the university, and which are distilled through every program.

PRACTICE-BASED LEARNING

Together with Pedagogy and Learning Spaces, this theme of PS2022 will explore the environment in which students learn, in terms of both the physical environment, the virtual environment, and the hybrid environment, and also how the learner best engages with their learning and their teachers. We will seek to explore how the defining philosophy and approaches of polytechnic education are implemented in today's polytechnics.

APPLIED RESEARCH

Applied research is targeted towards finding solutions (for real world problems). That is in contrast to basic research, which in principle is searching for new questions. Hence there is a difference in aspects like funding, cooperation and necessary competences between those. As example, applied research usually needs a team of experts in very different disciplines to work in an interdisciplinary way. At PS2022 we will explore how to run applied research in parallel to intensive teaching loads and how to integrate students into the research for better results and to teach them to become successful applied researchers.

EMPLOYABILITY AND GRADUATE SKILLS

A defining feature of the modern polytechnic is that it seeks to cultivate learners with career ready professional competences, while at the same time not losing sight of the intrinsic value of education. While the contexts of many of the PS2022 faculty participants may vary, they all share a common challenge of nurturing employability and graduate skills within students. This theme touches on what those skills should be, and how acquiring them can be built into the curriculum. There is also the natural tension between the needs of employers, and the needs of the individual with regards to these skills. This theme will be explored with input from industry and university leaders from different countries.

INTERNATIONALISATION, GLOBAL TEACHING & COLLABORATION

The modern university is an international oasis, in which learners from many different countries and regions converge in-person and virtually to acquire and share knowledge and skills. The act of being immersed within an international learning environment itself can be an enriching experience, and universities actively seek to broaden their student base and that of their faculty. This theme will be explored from the perspective of the benefits of internationalizing the university and the curriculum, but also from the perspective of the inherent advantages and challenges in doing this.

SUSTAINABILITY THEME

h_da has set as one of its ambitions to drive societal changes, to be a voice for sustainability, and a way of living and working in a new, more balanced way, a way that protects our planet for future generations. We are the only university in Germany currently, to offer a PhD title in sustainability. This PS2022 theme seeks submissions from across the globe on how others are championing sustainability and incorporating it into strategic goals, curricula and programs. This theme includes more than environmental sustainability, but also equity, social justice and economic development.

POLYTECHNIC SUMMIT 2022 IN DARMSTADT 28-30 JUNE

You are reading the Proceedings of the Polytechnic Summit 2022 hosted by Darmstadt University of Applied Sciences. After the fully digital version in 2021 for the first time in 2022 it was organized in hybrid form. National and international speakers, researchers and guests were discussing new teaching and learning formats and talked about, what applied research and the university of the future should look like.

We need applied sciences. The findings of applied sciences are essential, whether in the quest for a sustainable economy, climate protection or the search for green and digital solutions. Moreover, current and future challenges facing society can be better mastered through cooperation across borders and by sharing knowledge. The Summit is an opportunity to exchange ideas, learn from each other and to strengthen cooperation to increase quality. The GPEA and the Summit have attracted attention at more universities on both sides of the Atlantic Ocean. We are discussing to expand the GPEA, whose European part could be formed by the EUt+ alliance. Moreover, a new GPEA charter is in progress, starting in 2023. The name will then be changed to „Global Polytechnic Education Alliance“.

The Summit and the proceedings give an insight of how the universities have coped with the pandemic, what new learning formats are suitable for future „normal“ teaching? But also, how do we have to prepare our students for working life and industry, what soft skills do they need, and how can young people by inspired to take up technical education and engineering training as early as possible?

Our shared vision within the GPEA is to inspire authors to join our polytechnic community and to spread our spirit about polytechnic education, for which reason our presented papers represent a broad range of themes.

I would like to thank everyone who contributed to the success of the Summit, especially to,

Diana Hintea, Coventry University

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Uwe W. Schulz, Lucerne University of Applied Sciences and Arts

Stephen Wittkopf, Lucerne University of Applied Sciences and Arts

Elizabeth Barajas, Purdue Polytechnic

Glendali Rodriguez, University of Wisconsin – Stout

Arnd Steinmetz
(President Darmstadt University of Applied Sciences)

SESSION PAPERS

FLOW AND AURA: ARTS AND CRAFTS PHILOSOPHIES MADE MANIFEST IN PRESENT-DAY, HANDS-ON RESEARCH

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ABSTRACT

Recognizing the importance of flow and aura in the making experience has special pertinency within the context of real-world, hands-on studio work and learning. The history of social commentary and material culture of the 19th century Arts and Crafts movement reinforces this connection when tested against a modern day folk art school experience, strengthening the association between happiness in work the meaning of crafted artifacts.

Keywords: Arts and Crafts, Aura, Flow.

1. INTRODUCTION

In the Fall 2022, I pursued a course of independent research in my MFA studies at the University of Wisconsin Stout to, in the words of my documentation, "Combine research and historical analysis of the early Arts and Crafts movement's material culture design and fabrication techniques with contemporary studio design practices into material culture deliverables and an academic paper with conclusions."

In the three years I've spent completing my graduate degree, I'd developed a particular interest in craft, as both an exercise in making, a description of skillsets and cultural storytelling. My independent study was an academic and creative journey into the world of the Arts and Crafts movement of the 19th century to understand why that time period had such an impact on our understanding of material culture, craft and making.

To aid my understanding and apply what I'd learned, I attended a class at North House Folk School in Grand Marais, MN, taking the four-day Decorative Ironwork Intensive course. I was completely new to the craft, never having trained in blacksmithing or ironwork, but would come to experience a master class in constructivist, unstructured learning where space and time disappeared into the blazing embers of a coal forge.

The experience at the forge, melding creativity with physical effort into a true artifact of material culture, only heightened my awareness of the impact of mass industrialization I'd been researching. Clearly, something valuable had been taken from the 19th century working class, and the social and labor related challenges it created fed the critiques of reformist thinkers, who correlated this "progress" with the degradation of happiness and moral decay. An assessment of industrialization and capitalism's impact on society, architecture and material culture of the period became the seed of the Arts and Crafts movement. To examine the movement's contemporary legacy and its relevance to our present approaches to polytechnic learning, work, and material culture I would have to experience its philosophies first-hand.

2. ARTS AND CRAFTS A BRIEF HISTORY

Having already invested six weeks of research on the Arts and Crafts movement prior to arriving on October 14 2021 for my class in decorative ironwork at the North House Folk School in Grand Marais, MN., I wanted to apply my humble understandings of the movement to my crafting experience at the school. I thought I would learn the about the skill of blacksmithing and the arts and crafts style, but discovered a connection between the experience of craft and making and my own sense of self-actualization.

Social change in early 19th century Great Britain happened at a withering pace, disrupting social strata and labor while the industrial revolution mechanized work, automated people's livelihoods and redistributed wealth. But with any change comes disruption and uncertainty, and the social and political commentary of the times weighed heavily on the minds of early dissenters. From this upheaval came the Arts and Crafts movement which evolved not to "...promote a particular style, but (to) advocate reform as part of its philosophy and initiated a critique of the social and artistic costs of industrial labor"(Obniski 2008). During the Victorian age "...modern machines replaced workers, [and] Arts and Crafts proponents called for an end to the division of labor and advanced the designer as craftsman." (Obniski 2008)

Critics such as Augustus Pugin (1812–1852) and John Ruskin (1819-1900), questioned the morality of automation and its impact on the common man through the lens of architecture, design and craft. Other than their denominational differences, Ruskin (Protestant) and Pugin (Catholic) both "could be said to have linked style with society, but not in the same sense. For whereas Ruskin discerned various human traits in architecture, then attributes these to the society responsible, Pugin identified Gothic (architecture) purely with medieval Christianity, which he regarded as the essence of Catholicism." (Conner 1978).

Ruskin is often pointed to as a greater influencer for the Arts and Crafts movement. Building on Pugin's thoughts, Ruskin abhorred architectural "deceptions" (untruths) and associated architectural integrity with the society from which it sprang and the human hands that made it. He asserted the truth and integrity of society at any given time in history was manifest through its architecture. Ornament should never be for the sake of ornament, but rather to convey beauty in truth. Mass production had made it all too easy to create ornament without function, beauty without meaning or purpose. To Ruskin, then design "deceptions" were leading indicator of the decline in design.

Ruskin's entry into critiquing material culture and industrialization, other than architecture, occurred after he attended the Great Exhibition in Hyde Park, London, from May 1st to October 15th 1851. His review of the exhibition provided a hard look at industrialization's impact on society, evidenced by the industrialized, over ornamented material culture represented at the exhibition. The writings became a scathing review and rebuke industrialization's influence on the 19th century's material culture and how it reflected the decline of honest truth and work in craft. Quality, truth and meaning of craft (material culture) had been replaced by scale and automation, division of labor, and the widespread industrialized ornamentation of objects and architecture.

If Ruskin was the seed of the Arts and Crafts movement, William Morris (1834-1896) was the plant (Nau 2019). Although Morris was just 17 at the time of the Great Exhibition, its influence and the writings of Ruskin would shape his life into the Arts and Crafts movement's other great proponent and influencer.

Ruskin was a thought leader in design and social issues of the industrial revolution. Morris had a more applied, hands-on approach built upon "...Ruskin's main themes, his love of medieval-ism, his conviction in the social importance or art, and his desire for a renewed unity of arts and craft, finding pleasure in labor and simple beauty" (Nau, 2019)

In 1861 Morris and associates established Morris, Marshall, Falkner & Co. focusing on decorative art and furniture manufacturing. Morris actively participated and contributed to the workforce labor and fabrication processes, showing a keen interest in the skills needed and quality control of the company's products. The firm's methods were heralded by contemporaries as being "akin to the old-fashioned days, when the handicraftsman took pride in his work and was not hidden from the buyers, middlemen and commission agents" (Nau 2019).

During the 1880's Morris's politics took a turn towards socialism and his writings and lectures became more focused on labor and the worker. To survive in the industrialized world, the Arts and Crafts movement would need to not only embrace truth and beauty in material culture, but also the health, wellbeing and happiness of the worker.

The combination of Morris' focus on craft AND the craftsperson inspired by nature and social reform helped usher in the next generation of Arts and Crafts thinkers, many of whom were architects themselves. As the 19th century progressed, the movement's new disciples and their practices "expressed much of the character of the Arts and Crafts Movement and, in particular, the focus to reunite design and handicraft, redefine the role of architecture within that cause, and improve(d) design standards by promoting rational design principles with regard to function, use of material and method of manufacture." (Gordon 2020)

The Arts and Crafts movement established its strongest social and design footholds in the late 19th century based on its sense of a holistic work/life balance that sought to both make functional, beautiful architecture and material culture while embracing happiness and work/life balance.

3. THE RECOGNITION OF AURA

Stepping into the blacksmithing stable at the North House Folk School property, I was immediately struck by its simplicity. Lacking any computers and no digital footprint at all, I was immersed in an analog world of hammers, anvils, tongs, long wooden worktables and very few chairs. The corners and floorspace were dominated by six large bituminous coal forges with adjacent hand-cranked bellows. The small group of learners, seven of us, were about to do something with craft roots stretching back to 1200 BCE (Brittanica 2021) with the beginning of the iron age. The necessity of tool use that drove early humans to metal smithing was refined over time, evolving not just into a utilitarian craft, but an artistic form of expression. In a sense, by engaging with this practice, we were stepping into time, history, and lore.

When Ruskin examined the attributes of architecture in Gothic Venice and associated them with the period's historical, moral, and cultural wellness, he was drawing a direct relationship between material culture and how its form and function manifested in the built environment. He recognized, through physical senses and experiences, the authenticity of workmanship and materials.

Hand forged iron and steel reflect this authenticity. As Mike Jones introduced the group to sample ironwork, there was no mistaking the nature and history of each artifact. Two examples might look identical in form and function, but at close inspection each hammer mark, twist, turn and profile retained the memory of its making.

In Walter Benjamin's seminal 1936 essay "The Work of Art in the Age of Mechanical Reproduction," he postulates about an object's uniqueness or "aura" that "the most perfect reproduction of a work of art(design) is lacking in one element: its presence in time and space, its unique existence at the place where it happens to be. This unique existence of the work of art determined the history to which it was subject throughout the time of its existence. The authenticity of a thing is the essence of all that is transmissible from its beginning, ranging from its substantive duration to its testimony to the history which it has experienced." Alyssa Frijey's 2017 thesis on material culture, "Aura of Authenticity: The impact of Original Objects in the Museum Guest Experience'' states "The argument regarding authenticity suggests that only through the object itself can historical connotation, social context, or associated meanings and value be conveyed." Additionally, the "aura" reflects an intrinsic value of identity of the maker, the point in time it was created, tools, the materials and labor (embodied energy) used and the geographic location of the making.

Our class of blacksmithing apprentices only needed to hear Mike's own reflections on the sample pieces to feel his personal attachment to their experience in making.

Mike's assignment prompt tasked the apprentices to find design inspiration in the Sun. To introduce the assignment, Mike began blending demonstrations of blacksmithing techniques with quiet encouragement and advice as we began crafting. We used chalk on the tables or floor to draft our ideas, and I elected to design and smith a standard fire iron (poker). Making fires in a wood burning stove had become a ritual every morning of winter at my home in northern Wisconsin. Our wood stove was a primary source of heat during the cold northern Wisconsin winters and I had an intimate connection with the unique value of the tool. It had potential as an "authentic" work of art" with "its basis in ritual, (and) the location of its original use value." (Benjamin - 1936).

The act of making itself has been tied, at times, to a specific set of beliefs, "The Shakers, the Roycrofters, the Amish, and the Mennonites all interwove doctrine, design and spiritual reward directly derived from handiwork and human connection to material, form, and resulting objects." (Richter-O'Connell 2015). In the case of the manifest products of making, Benjamin applies the intrinsic value to the object itself, recognizing the history of cult, ritual and/or tradition with the associated material culture "We know that the earliest artworks originated in the service of a ritual – first the magical, then the religious kind. It is significant that the existence of the work of art with reference to its aura is never entirely separated from its ritual function."

The first fire iron design was untenable. Functional and refined in form, but beyond my ability to fabricate with so little experience. I spent the first day trying and failing to execute on that design and realized by early evening I needed to re-think the approach. In the morning, Mike and I reflected on my learnings, and a new design was born.

Although we may not see the trial and error leading up to a finished piece, when a thing is crafted and we study it through its material culture, it assumes a mantle, or aura, which observers and people interacting at any given time and place associate with: The signature and experience of the Maker in the form of effort, skills, knowledge and intent (virtues/vices)

- The time and place, when and where the object was created
- The materials, labor and tools requirement to fabricate
- The object's intended ritual or application

Whether Ruskin, Morris or Pugin (for that matter) would describe the built environment in quite this way is arguable, but they established an affinity between the intention and making of a thing and a perceivable aura of the finished product which an observer can interpret as its purpose and meaning.

4. HAPPINESS, FLOW AND MAKING

In the Arts and Crafts traditions of Ruskin and Morris the creative and maker processes best suited to producing truth and beauty in material culture can only be produced by honest work.

Blacksmithing is nothing, if not honest work. Each day of the blacksmithing class left me exhausted, mentally and physically. But as I grew more comfortable swinging the hammer and heating metal, I began to understand the color and plasticity of steel at high temperatures and how to literally bend the material to my will.

In Ruskin's Seven Lamps of Architecture, he asserts "If the man's mind as well as his heart went with his work, all this will be in the right places, and each part will set off the other; and the effect of the whole, as compared with the same design cut by a machine or a lifeless hand, will be like that of poetry well read and deeply felt to that of the same verses jangled by rote."

Ruskin considered the dehumanizing impact of separating creative work from manual labor, arguing a creatively fulfilling endeavor or job must marry the two. He called for "a right understanding ... of what kinds of labor are good for men, raising them, and making them happy" and a "determined demand for the products and results of healthy and ennobling labor." His "right understanding" and "ennobling labor" states "the observance of three broad and simple rules" (Popova 2015):

- Never encourage the manufacture of any article not necessary, in the production of which Invention has no share.
- Never demand an exact finish for its own sake, but only for some practical or noble end.
- Never encourage imitation or copying of any kind, except for the sake of preserving records of great works.

It's the conceptualization and idea first, and then the skills and effort to deliver the invention. Avoid separating the head and hand. These two things should always be coupled tightly together in the making process. It's the evaluation process and micro adjustments that happen in the crafting and making experience that separate it from mass production.

John Dewey (1859 - 1952) - an American philosopher, psychologist, and educational reformer whose ideas have been influential in education and social reform, led progressive discussions about categorizing craft and vocational education as something he called "Experience" (Dewey 1938), an important aspect to human learning. This "experience" of materials produced a physical and mental readiness as an interaction between object and processes.

So, when the head and hand are allowed to focus singularly on an activity like blacksmithing in a constructivist learning environment like North House, the unstructured classroom spaces give would-be-designers (all of us) the opportunity to associate personal interests with lore and hands-on skill building in discreet, timeboxed encounters.

Ruskin also stated people should be happy in their work, and to do so they need three things: (Binyon 1920)

- They must be fit for it.
- They must not do too much of it.
- And they must have a sense of success in it.

For large chunks of my blacksmithing crafting, I lost all track of time and space, only interrupted by moments of reflection, adjustments to the design and fabrication, physical breaks to relieve fatigue, and demonstrations of techniques by the instructor.

Ruskin could be said to have weaved "hand, heart, intellect and design into a process of imagining and making and to the resulting fruits of labortangible and intangible." (Richter-O'Connell 2015)

During my own blacksmithing crafting, I experienced periods of concentration that caused me to lose track of time and space, only interrupted by moments of reflection, adjustments to the design and fabrication, physical breaks to relieve fatigue, and demonstrations of techniques by the instructor. Counterintuitively, it was is the constrained aspects of space(my corner of the blacksmithing stable) and time (the four days we had in class) (Cleese 1991), that allowed me to be fully immersed in the creative process of making.

Mike's encouragement and small pointers kept me moving with the least number of barriers and friction in my work, and I was completely content in the effort. At that time and place, I was totally immersed and completely satisfied.

The early Arts and Crafts positions on work satisfaction from Ruskin (and Morris) may be mapped a modern model for personal contentment in work put forward by Mihaly Csikszentmihalyi (chik·sent·mee·hai·ee) in 1990, "Flow: The Psychology of Optimal Experience"

Contemporary writers have established a connection between 19th century Arts and Crafts sensibilities with this modern-day psychology. "...Just as William Morris, John Ruskin, Walter Crane, May Morris, Philip Webb, and all the craftsmen of the Arts and Crafts movement, some of us have felt the lack of connection. Some authors call this "flow," (Chemin 2020)

In Csikszentmihalyi's book he describes the flow state; a state of consciousness analogous to being in "the zone" in the popular culture vernacular. It is a mental state one enters while performing some activity ("making" in the context of crafting and material culture), fully immersed in a feeling of stimulated focus, complete involvement, and enjoyment in the activities' process. It makes a person feel like we don't exist. The mind is unable to feel anything other than the focused "flow" activity. What we think of existence seems to disappear because our mind can only process so much data at one time. This is psychological science." (Csikszentmihalyi 2008)

According to Csikszentmihalyi, there are eight characteristics of being in a flow state:

- Complete concentration on the task.
- Clarity of goals and reward in mind and immediate feedback.
- Transformation of time (speeding up/slowing down).
- The experience is intrinsically rewarding.
- Effortlessness and ease.
- There is a balance between challenge and skills.
- Actions and awareness are merged, losing self-conscious rumination.
- There is a feeling of control over the task.

The correlation between humankind's instinctual desire to make things and be happy doing it (as described by Ruskin and Morris in 19th century thinking) and the findings of modern-day psychological study is arguable.

My personal journey as a blacksmith apprentice at the North House clearly included time in flow, as evidenced by multiple periods of timeless focus on crafting with manifest contentment. I felt very happy!

5. CONCLUSION

What early 19th century architects, writers, philosophers, architects and designers such as Ruskin and Morris tried to convey was how the industrial revolution, mechanization of craft, and its dependence on the working class dehumanized the experience of "making" as an act of personal satisfaction and happiness. This was evident in architecture and material culture of the 19th century industrial revolution, its ability to mechanize ornament, and produce low quality goods lacking the aura of handcrafted works.

If the Arts and Crafts movement was making a case that we society has an obligation to the happiness and integrity of its workers and material culture, this making "Experience"(in Dewey's own words) is key to cultural stewardship. Per the UNESCO findings from "Traditional Craftsmanship in 2003," "Traditional craftsmanship is perhaps the most tangible manifestation of intangible cultural heritage." Safeguarding the knowledge and enabling craftsperson's to pass on their wisdom and techniques to others helps feed and sustain communities of practice, as well as each ennobling the labor in our community material cultures.

If the underlying premise of material culture is "... that objects made or modified by man reflect, consciously or unconsciously, directly or indirectly, the beliefs of individuals who made, commissioned, purchased, or used them, and by extension the beliefs of the larger society to which they belonged." (Prown 1982), then the industrial revolution undermined truth and beauty in Victorian society as evidenced by low quality work and unhappy workers.

As Makers, we cannot turn our back on the lessons and wisdom of history. The experience at the North House Folk School helped me connect my historical understanding the Arts & Crafts philosophies as presented by Morris, Ruskin, and their contemporaries with modern observations on aura and flow. Although I have analyzed and discussed it here, my participation in the physical blacksmithing crafting process was something that requires the full experience of hands-on education to fully understand. The flow state that one enters serves as a moment of human self-actualization, resulting in the creation of artifacts with material culture "aura". We perceive this "aura" as an association of maker, time and place, materials, labor, tools and ritual given to the crafted artifact and it serves as a set of unique markers for both makers and observers. As design curricula have been evolving to support online education and specialist credentialing, they would ultimately do well to embrace the full scope of hands-on, applied research, from theory and philosophy to the practicalities of making, building, and crafting.

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HYDRAULIC GRIPPER DESIGNS FOR ENHANCING CONSTRUCTION ROBOTICS AND AUTOMATION

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ABSTRACT

The construction industry significantly relies on hydraulic systems for high power applications and precise control. Most construction equipment utilizes hydraulic power due to its fast dynamic response, flexibility in transmission, ease of operation, high actuation power, and controllability. Despite the prominence of fluid power technology and its considerable potential in achieving high power capacities and efficient overall performance, productivity indicators reveal that the conventional construction methodologies have reached their possible technological limits. This limitation is due to the technological inadequacies arising from inappropriate human working conditions, lack of safety, and workforce shortage. Subsequently, this leads to quality defects and cost overruns, constricting work productivity and impeding the industry's economic growth. Therefore, the construction industry started incorporating automation and robotics technology to enhance productivity, safety, and sustainability. However, this groundbreaking technology is still incapable of fully applying such technological strategies due to various challenges, such as economic hurdles, the dynamic nature of the construction, the diverse workforce, and the complexity of the technology. Thus, this work exhibits an applied research work that could be conducted in the construction robotics field to benefit from this groundbreaking technology. It investigates the development of automated construction systems that can be integrated into the existing construction machinery. New conceptual designs are proposed for a hydraulically actuated automated gripper that can be mounted on existing commercial cranes for lifting, loading, and handling construction objects. Three conceptual mechanical designs for the hydraulic automated grippers are presented, along with their main features, applicability, and operation.

Keywords: hydraulics, applied research, mechanical design.

1 INTRODUCTION

Fluid power is the technology that relies on hydraulic energy stored in the form of pressurized fluid to produce, control, and transmit power, thus achieving diverse mechanical actuation [1] [2]. The utilized fluid is typically hydraulic oil due to its low freezing point, high boiling point, relatively large bulk modulus, oxidation stability, and wear resistance. This pressurized fluid serves as a self-lubricant for the fluid power systems' components, contributing to their performance and extending their life service [3]. Given these characteristics of hydraulic oil, hydraulic systems enable generating high forces and power to weight ratios, making it convenient for heavy-duty applications that require high power densities and ample heat transfer and contamination control [4]. Besides achieving high power densities, hydraulic systems are characterized by their fast dynamic response, flexibility in transmission, ease of operation, system responsiveness, and controllability and versatility [5] [6]. These advantages make fluid power technology an attractive research area to many scholars. Given its well-established research area and scholarly activities, fluid power technology has been serving widespread industries like agriculture, transportation, construction, aerospace, manufacturing, and many other industrial applications requiring fast energy capture and high actuation power [7] [8].

Amidst many industries, the construction industry uses hydraulic machinery to generate powerful motion and attain precise control. It utilizes hydraulic construction equipment to achieve fast energy capture and high actuation power. It is estimated that the construction equipment comprises around 76% of the total hydraulic equipment [9]. The construction industry relies on modular hydraulic construction equipment that uses compact hydraulic construction attachments to achieve various tasks, e.g., handling, gripping, loading, drilling, hammering, etc. The hydraulic construction attachments allow for modularity in the equipment's design, where a single machine can be used for multiple purposes on a construction site. Such a design feature significantly increases construction equipment's power capacities and work productivity, enabling more work to be done in less time [10].

Despite the significance of hydraulic machinery in improving the construction industry's work productivity, industrial productivity indicators reveal that the conventional construction methodology has reached its possible technological limits [11] [12] [13]. This limitation is due to the technological inadequacies arising from inappropriate human working conditions, which causes quality defects and cost overruns [11]. Construction site environmental conditions expose laborers to hazardous consequences, such as chronic fatigue, injuries and illnesses, and severe musculoskeletal disorders [14] [15]. As a result, this aftermath leads to a significant decrease in laborers' motivation, low work quality, and poor judgment, thus negatively impacting work productivity and causing job dissatisfaction [16] [17]. For this reason, the construction industry started adopting construction automation and robotics that have the potential to improve work productivity and enhance construction efficiency [11] [13]. Construction automation and robotics refer to incorporating computer numerical control and real-time sensing technological strategies, e.g., robotics and automated systems, into the conventional construction equipment [18] [19]. It is a new machine-centered construction technology that allows applying robotic systems in the construction field [20]. Applying this groundbreaking technology is crucial and adds valuable benefits to the construction industry. It aims to improve sustainability efforts, enhance work productivity, create new job opportunities for skilled workers, and boost the industry's economic growth. Accordingly, automation and robotics technology has been used on construction sites for performing multiple tasks, such as fitting interior walls, helping to carry masonry blocks, and driving forklift trucks and diggers [21].

Given the significant potential of construction automation and robotics in reinforcing the industry's sustainability, there has been a surge in research in recent years for investigating the development and adaptation of various technologies to support robotics automation in construction. The research was pivoted on building information modeling (BIM) [22] [23], computer vision [24] [25], artificial intelligence [26] [27], game simulation [28] [29], virtual reality, and augmented reality [30] [31]. However, the research mainly focuses on adapting construction automation and robotics technology and integrating them with other (above-mentioned) technologies. Thus, the existing research and scholarly activities lack the investigation of integrating automation and robotics technologies with hydraulic power, which is the theme of this paper.

This paper is organized as follows. Section 2 introduces the challenges obstructing this technology from fully integrating into the construction industry. It exhibits the critical hurdles in construction automation and robotics reported by many academic researchers in the construction field. Section 3 presents an applied research work for overcoming some of the presented challenges by proposing multiple conceptual paradigms for a modular hydraulically actuated gripper. Throughout this section, three different conceptual designs are proposed for developing a modular hydraulic automated gripper that can be mounted on existing commercial cranes. Section 4 concludes the work.

2 CHALLENGES IN CONSTRUCTION AUTOMATION AND ROBOTICS

Despite the prominence of construction automation and robotics technologies and their considerable potential in addressing the various construction shortcomings, the construction industry is still incapable of fully integrating such technological strategies due to multiple challenges [32]. Studies reveal that the technology of automation and robotics has not been totally adopted on construction sites by the U.S. industry, where it is delayed due to many hurdles [33] [34]. As identified by academic researchers, such hurdles are related to economic, industry-intrinsic, workforce, and technological challenges [35].

From the economic aspect, applying automation and robotics on construction sites has many uncertainties, exposing construction companies to high financial risks [36]. Given that the implementation of construction robotics requires a very high capital investment, several construction companies are unassertive toward applying this groundbreaking technology. Accordingly, the companies’ reluctance toward testing new technological construction techniques impacts the adoption of robotics technology [37].

In addition to the economic infeasibility, the dynamic-intricate nature of construction sites and the inadequate research investments in construction automation and robotics are considered other critical hurdles. It is claimed that the conducted research studies in the construction field are uncorrelated with the construction automation practices, and thus such scholarly activities impede the industry’s innovative culture [38].

Like the previously mentioned challenges, the workforce challenges significantly impact adopting automation and robotics on construction sites. Such challenges are related to the hurdles associated with the robot-human interaction, unskilled labor force, the surge of workforce shortages, and job security [33]. Although the advancements in artificial intelligence allow achieving high safety measures and facilitating the robothuman interaction, the workforce lacks the required skills to interact and deal with robotic inventions. There are no sufficient pedagogical training sessions to develop the necessary skillsets and prepare the workers for such an experience [39].

Besides these challenges arises the technological challenges, which also obstruct the incorporation of automation and robotics on construction sites. These challenges are due to the complexity of designing and implementing modular automated construction systems and the lack of standardization and regulation [33]. Designing modular automated construction equipment is crucial, where it comprise interchangeable parts that allow for serving more than one application. This feature permits utilizing the same equipment for multiple purposes on a construction site. Since almost all the existing robotics construction equipment lack design flexibility and modularity, sudden changes in any construction parameter could disrupt the whole construction operation [40].

Given these existing challenges, it is required to investigate neoteric techniques and strategies for developing automated construction systems that can be integrated with the existing construction machinery. More research and scholarly activities should be conducted in the construction robotics field to benefit from this groundbreaking technology, i.e., robotics and automation technology. A clear systematic research plan must be embraced to address all the existing challenges, thus improving productivity and enhancing the nature of the construction industry.

3 MODULAR HYDRAULIC AUTOMATED GRIPPERS ON CONSTRUCTION SITES

The existing challenges in construction robotics and automation necessitate proposing new technological methodologies to promote the adoption of robotics and automation technology on construction sites, improving construction productivity and reinforcing economic growth. Therefore, this work proposes developing modular hydraulic automated grippers that can be installed on existing commercial overhead/tower cranes by incorporating mechanical engineering technology into construction management.

Multiple conceptual gripper designs are proposed to overcome some of the preintroduced challenges and achieve desired construction tasks. The proposed grippers allow flexibility and modularity in the design and have various technological benefits in construction automation and robotics. They are hydraulically actuated flexible attachments capable of mounting onto existing overhead/tower cranes for gripping, lifting, and loading common objects used in construction practices, e.g., I-beams, steel columns, masonry blocks, concrete slabs, wood frames, etc. Thus, the proposed grippers serve as crane-attachment futuristic construction machinery to attain various mobilization of construction objects through the utilization of a hydraulic-powered gripping mechanism.

We propose three different conceptual designs for the hydraulic automated grippers throughout this work. Each of the proposed automated grippers comprises two subsystems: mechanical and hydraulic. The mechanical subsystem involves the mechanical paradigm of the gripper, e.g., gear train, shafts, joints, flexible brackets, sliders, etc. The hydraulic subsystem consists of the corresponding hydraulic circuits encompassing the hydraulic units and components, like the pump, hydraulic actuators, valves, etc. The following three subsections, respectively, present the proposed mechanical models (modularity of the designs), the corresponding hydraulic circuits for the three different conceptual designs, and the flexibility of mounting the grippers on existing overhead/tower cranes.

3.1 THE MODULARITY OF THE MECHANICAL DESIGNS

Three different conceptual mechanical paradigms, elucidated in Figure 1, Figure 3, and Figure 5, are proposed for addressing the predefined problem. The three gripper paradigms allow for modularity and flexibility in the gripper's design, where the same gripper can be readily integrated with the existing construction machinery. Also, given the modularity feature, each of the three proposed grippers is capable of gripping any construction object on the construction site, like masonry block, I-beam, plates, etc. The following subsections present the design features for the three mechanical paradigms: first, second, and third conceptual design, respectively.

3.1.1 FIRST CONCEPTUAL DESIGN

The conceptual design shown in the diagram of Figure 1 illustrates a compact paradigm for the hydraulically actuated gripper that can be mounted on existing commercial cranes for gripping, lifting, and loading construction objects (I-beams, steel columns, and wood frames). The diagram shows that this proposed mechanical design comprises two primary mechanisms: gripping and rotating.

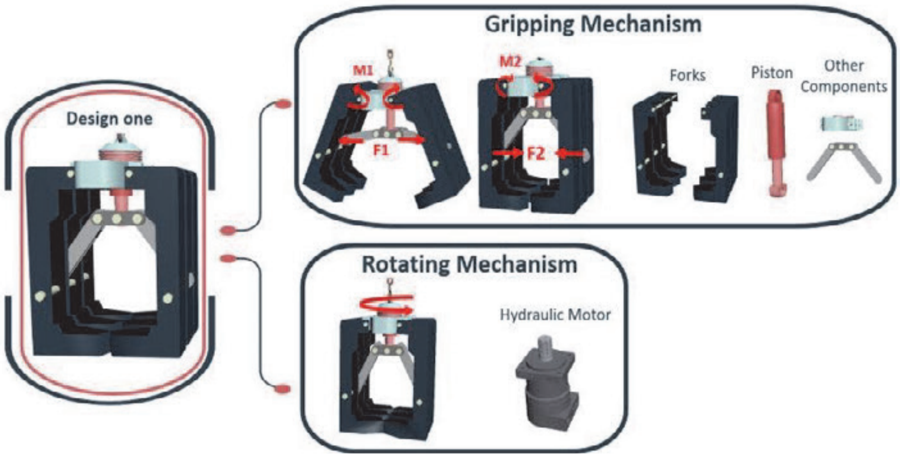


Figure 1: Diagram illustrating the two fundamental mechanisms involved in the first conceptual design and the corresponding components.

The gripping mechanism involves the hydraulic linear actuator (piston), right-angle forks, and other mechanical components, e.g., revolute joints, mounting brackets, cover, flange, etc. The gripping mechanism is hydraulically powered, where it uses a hydraulic pump to extend and retract the linear actuator that allows controlling the opening and closing of the forks. For instance, extending the hydraulic piston creates a positive moment M1 on the revolute joints, thus applying a force F1 on the forks to open. However, retracting the piston generates a negative moment M2 on the joints, forcing the forks to close. Given the power of hydraulic fluid, it is possible to control the opening and the closing range of the forks by controlling the amount of the pumped fluid, which enables locking the piston's rod at a specific position.

Besides the gripping mechanism, the rotating mechanism adds additional design flexibility. It allows rotating the gripper around its center of gravity, thus achieving various mobilization of construction objects. Accordingly, this mechanism is simple and compact, where it uses a hydraulic motor to attain the rotational motion of the gripper. Therefore, the utilized gripping mechanism allows for handling, lifting, and rotating several standardized sizes of I-beams, steel columns, and wood frames, as shown in Figure 2.

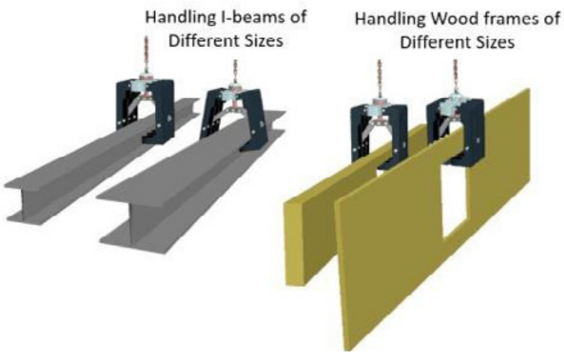


Figure 2: Gripper capable of handling multiple construction objects.

3.1.2 SECOND CONCEPTUAL DESIGN

The second design, shown in the diagram in Figure 3, demonstrates another achievable paradigm for the hydraulically actuated gripper. Similar to the first conceptual design, this design allows for flexibility and modularity. It could be attached to any commercial overhead/tower crane to load, lift, rotate, and grab construction merchandise. The figure shows that this design encompasses two fundamental mechanisms: sliding and rotating.

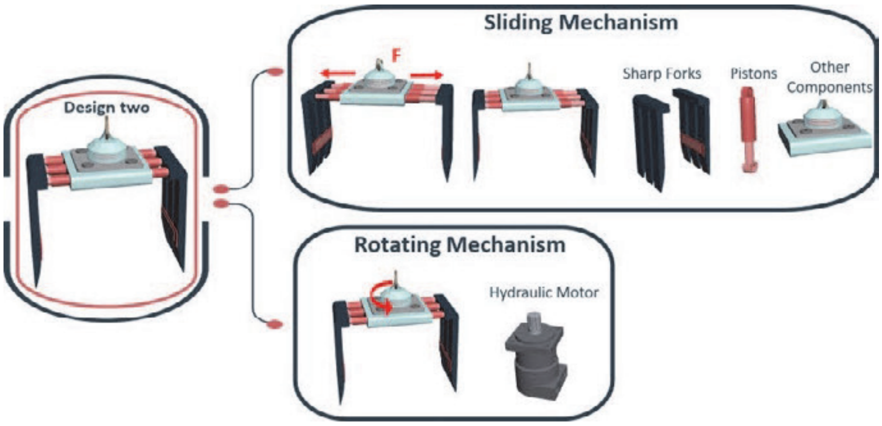


Figure 3: Diagram illustrating the second conceptual design, its primary mechanism, and the corresponding components.

The sliding mechanism consists of six hydraulic linear actuators (pistons), forks, and other mechanical attachments (friction pads and cover). Given that the gripper is hydraulically actuated, a hydraulic pump is utilized for extending and retracting the pistons. This mechanism allows controlling the pistons' positions which permits controlling the opening range of the gripper, thus attaining various openings. Friction pads are added to the design to prevent the items from slipping and protect the objects during loading and unloading. Like the previous design, the rotating mechanism comprises a hydraulic motor that allows turning the gripper 360 degrees around its center of gravity. The flexibility of both mechanisms enables the loading and handling of various construction objects of different sizes. For instance, Figure 4 shows how this gripper can load multiple construction merchandise.

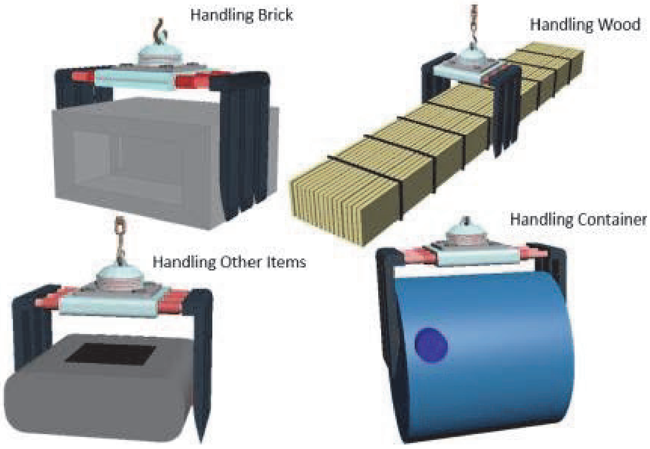


Figure 4: Another conceptual design of the gripper capable of handling multiple construction objects.

3.1.3 THIRD CONCEPTUAL DESIGN

Compared to the first and second conceptual designs, the third design of the hydraulically actuated gripper, shown in Figure 5, allows for a high degree of flexibility. It integrates three different mechanisms: gripping, sliding, and rotating, where it utilizes the gripping feature of design one and the sliding feature of design two.

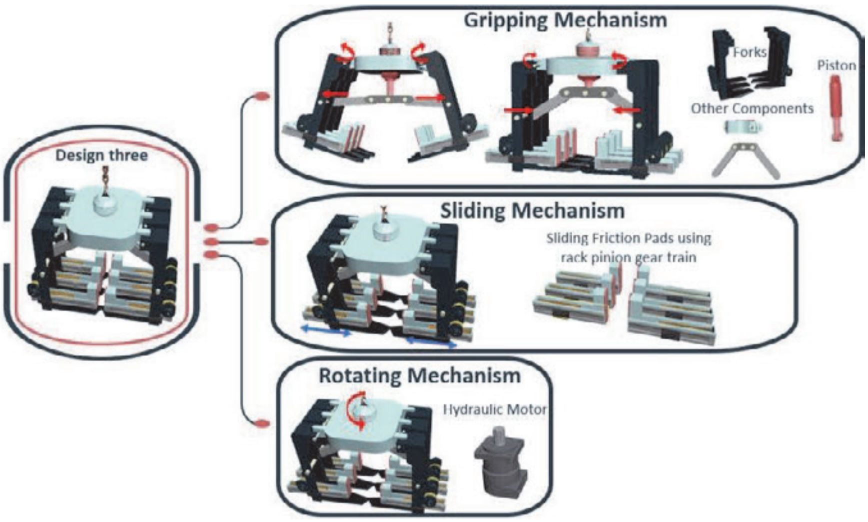


Figure 5: Diagram illustrating the third conceptual design, its primary mechanism, and the corresponding components.

Like the first design, the gripping mechanism in design three comprises a hydraulic linear actuator installed with a hydraulic pump, right-angle forks, revolute joints, etc. The opening and closing range of the forks is hydraulically controlled by controlling the rod's position (extending and retracting the hydraulic linear actuator). Besides the gripping mechanism, a sliding mechanism is employed to achieve a higher degree of flexibility in controlling the forks' opening and closing range, thus achieving various object dimensions. The sliding mechanism involves mechanically actuated sliding friction pads, rackpinion gear trains, prismatic joints, shafts, and guard-to-machine attaching mounting brackets. The friction pads can slide on the forks to attain different objects' sizes while the forks are fully closed. This mechanism is accomplished using the rack-pinion gear trains installed on the forks. The rack is rigidly attached to the friction pads that are linked to the forks using prismatic joints; however, the pinion is mounted on a shaft using mounting brackets directly connected to the forks. So, the rotational motion of the pinion generates a linear motion on the rack, thus allowing the friction pads to slide on the forks. In addition to the gripping and sliding mechanisms, the rotating mechanism enables turning the gripper 360 degrees around its center of gravity. Therefore, this design combines the merits of the previous two designs, adding a higher degree of flexibility in gripping and handing construction objects.

Figure 6 shows that the utilized mechanisms enable handling diverse construction merchandise with variable sizes while protecting the items and preventing them from slipping during loading and unloading. Although this design surpasses the first and second designs, it encompasses some drawbacks. Even though the sliding mechanism adds flexibility and modularity to the design, it makes the procedure more complicated and intricate.

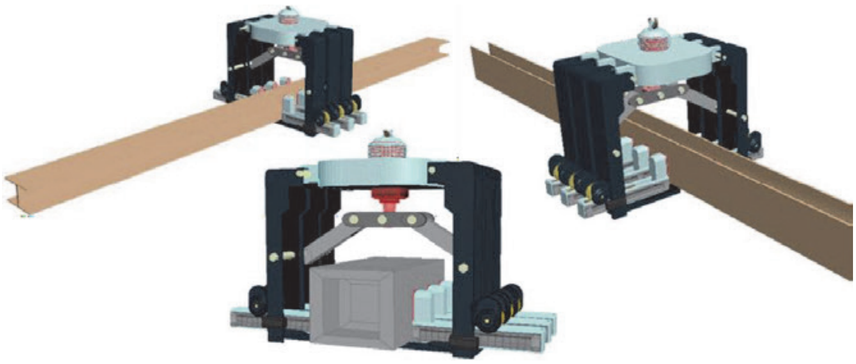


Figure 6: A third conceptual design of the gripper capable of handling masonry blocks and I-beams of a wide range of sizes.

3.2 HYDRAULIC AUTOMATED SYSTEMS

After presenting the three proposed mechanical paradigms for the gripper, we introduce the corresponding hydraulic systems throughout this section. The following subsections present two hydraulic circuits: one for achieving the sought-after mechanisms of designs one and three and one for attaining the required mechanisms of design two.

3.2.1 HYDRAULIC CIRCUIT OF THE MECHANICAL DESIGNS ONE AND THREE

Given that the gripper's first and third conceptual designs use similar gripping and rotating mechanisms, the same hydraulic circuit can be adopted. Figure 7 shows the scheme of the hydraulic system responsible for operating the gripper in designs one and three. The intended hydraulic system comprises a fixed displacement hydraulic pump (4) to pump pressurized fluid into the hydraulic piston (7) and the hydraulic motor (9). Two 4-way, 3-position, solenoid-operated directional control valves (5a) and (5b) are employed throughout the circuit to control the gripping and rotating mechanisms independently.

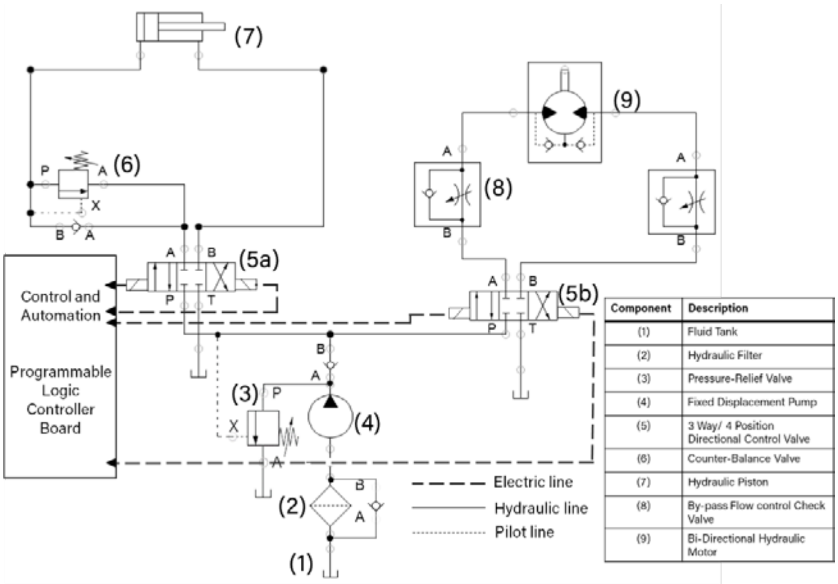


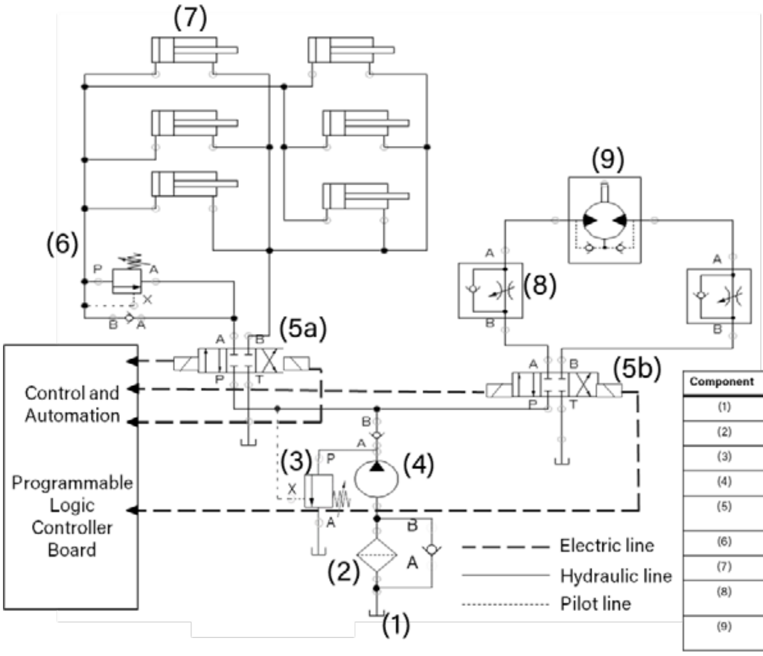
Figure 7: The hydraulic circuit adopted for designs one and three.

Valve (5a) allows extending and retracting the piston, thus controlling its position. For instance, actuating the left position of the valve (5a) allows extending the hydraulic piston; however, actuating the right position allows retracting the piston. Given that the extending velocity is greater than the retracting velocity because of the piston and cylinder areas, a counterbalance valve (6) is installed at the outlet port of the piston. The counterbalance valve manages the piston's velocity during retraction to prevent rapid piston retraction. Valve (5b) enables controlling the motor's direction of rotation. Pumping fluid through the valve's position one allows the motor to rotate clockwise; however, pumping fluid through position three allows the motor to rotate in the reverse direction, i.e., counterclockwise. Given that the gripper's application requires a lowspeed operation, two by-pass flow control check valves (8) are utilized for controlling the motor's velocity. A metering-out hydraulic configuration is adopted, where the flow control valves (8) are connected at the motor's inlet and outlet ports. Besides the preintroduced valves (5), (6), and (8), a pressure relief valve (3) is added to control the system's pressure surges, thus protecting the system against failure.

A Programmable Logic Controller (PLC) system integrator is installed to allow for a seamless operation of the hydraulic circuit. The PLC is responsible for system automation. It will enable receiving input sensor data and transmitting outputs based on the pre-programmed parameters. The PLC's utilization allows monitoring and recording runtime data, such as operating pressure, piston's position, gripper's productivity, generation of alarms, etc. It serves as a robust and flexible manufacturing process control solution adaptable to the gripper's application

3.2.2 HYDRAULIC CIRCUIT OF THE MECHANICAL DESIGN TWO

Figure 8 shows the scheme for the hydraulic system responsible for operating and controlling the gripper system of design two. The hydraulic circuit adopted for design two is similar to the one in Figure 7 (circuit used for designs one and three); however, the circuit in Figure 8 utilizes six hydraulic pistons (7) instead of one. Thus, like the circuit in Figure 7, a hydraulic pump (4) is used for pumping fluid into the hydraulic pistons (7) and the bi-directional hydraulic motor (9) that are independently controlled using the directional control valves (5a) and (5b). Similarly, a counterbalance valve (6) is added to control the pistons' speed during retraction, thus preventing sudden rapid retraction. Also, two flow control valves (8) are connected at the motor's ports to achieve a seamless gripper's rotation. The hydraulic circuit is monitored and controlled using a PLC system integrator like the previous circuit.



Component	Description
(1)	Fluid Tank
(2)	Hydraulic Filter
(3)	Pressure-Relief Valve
(4)	Fixed Displacement Pump
(5)	3 Way/ 4 Position Directional Control Valve
(6)	Counter-Balance Valve
(7)	Hydraulic Piston
(8)	By-pass Flow control Check Valve
(9)	Bi-Directional Hydraulic Motor

Figure 8: The hydraulic circuit adopted for design two.

3.3 THE FLEXIBILITY OF MOUNTING

Throughout this subsection, we present the flexibility and ease of mounting the gripper on existing overhead cranes by adopting the overhead bridge crane present in our construction lab (D. Dorsey Moss Construction Lab at Purdue University).

The adopted crane is shown in Figure 9. It is a heavy-duty circular lifter comprising a 2-ton hoist with a pulley linked to a peerless hook, the cross rail, the circular monorail, and the mounting trolley. The hoist can move horizontally (1) along the cross rail and vertically (2) through its pulley mechanism. Besides the horizontal and vertical translational motions, the hoist can travel in the radial direction (3) at a full 360°, where the cross rail is capable of rotating around the mounting trolley on the circular monorail. Thus, the adopted overhead crane allows 3 degrees of freedom (3DOF), where the hoist can travel (1): horizontally, (2): vertically, and (3): circumferentially.

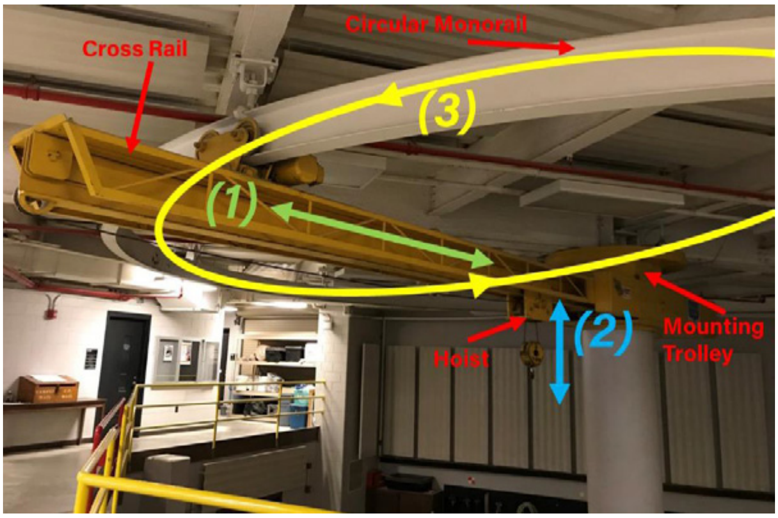


Figure 9: Overhead crane located in D. Dorsey Moss Construction Lab at Purdue University

The grippers illustrated in Section 3.1 can be safely mounted on the crane through the employment of the peerless hook. The three proposed designs involve a high-strength hoist ring linked with the gripper's cover to allow for safely hooking. The utilization of the hoist ring allows for safety attaching/ detachment of the gripper from the crane. Furthermore, given the gripper's rotating mechanism, attaching the gripper to the crane will allow rotating the object around its center of mass, thus achieving an extra degree of freedom. This feature allows for controlling the object's orientation and position, thus attaining a high range of flexibility.

Although attaching the gripper using the peerless hook is simple, easy, and safe, it might cause some vibrations and oscillations, leading to heavily shaking of the construction merchandise. For this reason, a linear quadratic regulator (LQR) controller will be designed for stabilizing the gripper's position by controlling the gripper's states, i.e., angle of rotation of the hydraulic motor, pistons' position, joint angles, etc. Besides stabilizing the gripper, the adopted control formulation will be augmented to minimize the controller gains, thus accounting for the energy optimization.

4 CONCLUSION

Construction automation and robotics is a new machine-centered construction technology that integrates automation and robotics systems in the construction field. It improves sustainability efforts and works productivity, thus boosting the industry's economic growth. Despite its considerable potential in improving the construction industry, construction automation and robotics are still not fully applied by construction companies due to many challenges, like high cost, complexity, robot-workforce interaction, etc. Thus, this work addresses the predefined problem by investigating the development of a hydraulic automated gripper that can be readily mounted on any commercial overhead/tower crane for lifting, loading, and unloading multiple construction merchandise. It proposes three possible conceptual paradigms for achieving the sought after tasks and investigates the applicability of each design, highlighting the flexibility and modularity of each. The proposed grippers are hydraulically-powered to allow heavy lifting and fast-energy capture. They can handle multiple heavy construction objects, e.g., I-beams, timber frames, masonry blocks, and other construction merchandise. The adopted mechanisms (gripping and rotating) enable safely grabbing and lifting the construction objects while achieving flexible mobilization. After finalizing and optimizing the gripper's design, a controller will be designed for stabilizing the gripper, thus minimizing any possible vibrations.

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MONITORING AIR POLLUTION LEVELS IN DRIVE-THRU ACROSS THE UK

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ABSTRACT

Air pollution is one of the leading causes of mortality, claiming thousands of lives every year. Although there is some limited literature on effects of pollution on outdoor workers, no study has evaluated the effects of pollution on drive-thru outlets. As vehicular pollution produces the highest levels of NO2 and particulate matters "PM" that's considered harmful to health, it becomes imperative to understand how this affects the drive-thru employees and users who are subject to inhaling this pollution over short-term periods or even long-terms. An awareness of the scale of the problem can significantly impact populations' attitude and behavioural change. Although there are permissible standards set by the government, no studies can assertively claim that an allowable level of air pollution as health can impact different groups of people differently. Vulnerable groups of people with underlying health effects can be impacted even at low levels of exposures. The knowledge and awareness of the population has to be enhanced by more dissemination and education. The overall aim of this project was to measure the levels of pollutants to raise awareness among employees and users of the dangers of the deleterious effects of pollution; to highlight that employers have the duty to protect the drive thru employees from the harmful effects of pollution and employ proper precautionary measures to minimise exposure and hence mitigate any possible damage to health and well-being. In this study, AQMesh combo monitors were mounted onto the back of vans that were parked near drive-thru outlets of 10 locations for fast food and coffee shops in the UK. Pollution levels were constantly monitored for two weeks and recorded at different intervals of time. The total number of incidents when the recorded level of different pollutants exceeded the standard permissible levels was investigated. The data was analysed to highlight the number of times when the pollution exceeded UK/EU standard levels. The study found levels of nitrogen dioxide and particulate matter peaking at many times the standard permissible limits. There were also persistent levels above the standard limit that would likely result in typical health effects, both short and long-term, as a consequence of high concentrations of air pollutants.

Keywords: Air Pollution, Contaminant Monitoring, Drive-Thru Air-Quality, Experimental Testing, Outdoor Air Pollution.

1 LITERATURE REVIEW

Air pollution is a mixture of natural and man-made substances in the air we breathe. It is typically separated into two categories: outdoor air pollution and indoor air pollution [1]. Outdoor air pollution involves exposures that take place outside of the built environment. Examples include:

- Fine particles produced by the burning of fossil fuels (i.e. the coal and petroleum used in energy production)
- Noxious gases (sulfur dioxide, nitrogen oxides, carbon monoxide, chemical vapors, etc.)
- Ground-level ozone (a reactive form of oxygen and a primary component of urban smog)
- Tobacco Smoke

Air comprises of natural gases and mainly consists of Nitrogen, Oxygen, Argon, Carbon Dioxide and a small amount of other gases [2]. Air is said to be polluted when it is contaminated by noxious gases and minute particles of solid and liquid matter (particulates) in concentrations that endanger health. Air pollution is the introduction of substances or energy into the environment, usually by humans, that are liable to cause hazard to human health and substantially harm living resources and ecological systems [2].

Air pollution is a complex mixture of gaseous and particulate compounds and, depending on their origins, can be classified as primary and secondary pollutants. Primary pollutants are those that are generally emitted directly into the atmosphere, whereas secondary pollution occurs due to chemical reactions that involve other pollutants. Carbon mono-oxide (CO) and Sulfur dioxide (SO2) are the primary pollutants; Ozone (O3) and Nitrogen oxides (NOx) are the secondary air pollutants in the air. Pollutants such as PM have both primary and secondary components [3].

Air pollutants can result from various sources and processes such as fossil fuel combustion in motor vehicles and industrial processes, from fires and volcanoes, gas burning appliances, kerosene space heaters and tobacco smoke. Residential wood burning, coal combustion and solar radiation react with molecular oxygen to form ozone in the stratosphere. Natural processes and human activities both contribute to the formation of ozone [3]. Table 1 lists common air pollutants and their sources.

POLLUTANT	MAJOR SOURCES
PRIMARY AIR POLLUTANTS	
CO	Motor Vehicles Engines on motorboats Lawnmowers Chainsaws Residential wood burning Improperly adjusted gas burning and oil appliances Coal combustion Tobacco smoking
SO_2	Burning of fossil fuels (coal and oil) Smelting of mineral ores that contain sulphur Diesel exhaust Volcanic eruptions
SECONDARY AIR POLLUTANTS	
NO_x	Combustion processes, such as heating Power generation Motor vehicle exhausts
O_3	Photochemical reactions in the presence of nitric oxide NO_2 and volatile organic compounds Fireworks
PRIMARY and SECONDARY AIR POLLUTANTS	
PM	Power station emissions Automobile exhausts (especially diesel vehicles) Road dust Other anthropogenic sources

Table 1. Common Air Pollutants and their Sources [3, 4] (Limaye and Salvi 2010; EPA 2012)

1.1 HEALTH EFFECTS OF POLLUTANTS

There are typical health effects, both short- and long-term, as a consequence of high concentrations of air pollutants. Short-term effects include irritation to the eyes, nose and throat, and upper respiratory infections such as bronchitis and pneumonia. Headaches, nausea and allergic reactions are other effects as a consequence of short-term exposure. The medical conditions of individuals with asthma and emphysema can be aggravated due to short-term air pollution [4]. Long-term health effects include chronic respiratory disease, lung cancer, heart disease, and even damage to the brain, nerves, liver, or kidneys. Continual exposure to air pollution affects the lungs of growing children and may aggravate or complicate medical conditions in the elderly [4].

Ambient air pollution has an important impact on morbidity and mortality. The World Health Organization ascribed 7 million deaths to environmental pollution in 2012 [5- WHO]. In most cities, vehicular emissions represent the main source of atmospheric pollutants, and both short- and long-term exposure to traffic pollution have been associated with adverse health effects [6]. According to Santos [6], several studies have shown an association between lung function decline and long-term exposure to air pollution in adults. Evidence that reduction in air pollution may improve lung function, as well as attenuate its decline with age, is also available.

Hypertension and outdoor air pollution are, respectively, the first and sixth overall risk factors for global deaths, accounting, respectively, for 10.5 and 4.3 million deaths in 2016 [7]. Cardiovascular diseases accounted for 55% of the deaths associated with air pollution, which is an independent risk factor for increased blood pressure [7]. In turn, altered blood pressure is one of the most important factors involved in cardiovascular morbidity and mortality. Although reduction of long-term exposure to air pollution is associated with increased survival [7], studies suggest that its impact on mortality persists for decades after exposure, similar to that observed with smoking [7].

Many studies have evidenced short- and long-term effects of exposure to air pollution on blood pressure. Investigations on chronic effects on blood pressure have increased and the results are not consistent, with some studies failing to detect a robust long-term effect. Challenges include monitoring temporal and spatial variation of exposure, variable chemical composition of air pollution, different age of study populations and difficulty in isolating other environmental and personal risk factors [7].

In Europe, air pollution represents the largest single environmental health risk. Over 90% of the European citizens are exposed to annual levels of outdoor fine particulate matter that are above what is specified in the World Health Organization's air quality guidelines. This exposition accounted for 482,000 premature deaths in 2012 from heart and respiratory diseases, blood vessels conditions and strokes, and lung cancer [8].

1.2 HISTORICAL PERSPECTIVE OF AIR POLLUTANTS

The relationship between urban air pollution and its effects on health have been known for centuries, the UK recognized air pollution as a public health burden since the 13th century [9]. The term smog, a combination of smoke and fog, was coined in 1905 [10], and this became a significant problem at the height of the Industrial Revolution between the 19th and 20th centuries [11]. The Industrial Revolution was initially seen as a symbol of growth and prosperity and no attempts were made to mitigate any air pollution problems.

It was events such as the 1952 Great London Smog that resulted in over 12,000 premature deaths [12], the air pollution issues in Donora Pennsylvania in 1948 [13] and the Meuse Valley episode in Belgium [14] that led to the formulation of policies and regulations for air quality control in the developed countries.

As a result of these policies and regulations, air pollution is considerably controlled in developed countries. This is demonstrated by the air quality concentrations measured and reported. National Ambient Air Quality standards are set for the most hazardous high-volume pollutants, called the criteria pollutants that include:

- Airborne Particles (PM)
- Sulphur oxides (SOx)
- Carbon monoxide (CO)
- Nitrogen oxides (NOx)
- Ozone (O3)
- Lead (Pb)

Developed countries such as the US and the UK periodically report the levels of the criteria pollutants in the air and the amounts of emissions from various sources to analyze how they have changed over time and summarize the current status of air quality [15].

1.3 AIR POLLUTION IN THE UK

For the purposes of air quality monitoring and assessment of compliance, the UK is divided into 43 zones [16]. In 2018:

- The UK met the limit value for hourly mean nitrogen dioxide (NO2) in 41 out of 43 zones.
- Seven zones were compliant with the limit value for annual mean NO2.
- The remaining 36 zones exceeded this limit value.

Poor air quality is the greatest environmental risk to public health in the UK. It is known to exacerbate the impact of pre-existing health conditions, such as respiratory and cardiovascular illnesses, especially for the elderly and infants. Nitrogen dioxide (NO2) is of particular concern because there is widespread exceedance in the UK, of limit values for this pollutant. NO2 is associated with adverse effects on human health. Estimating the long-term impacts of NO2 pollution is difficult, because of the challenge of separating its effects from those of other traffic-related pollutants. Particulate matter is also of concern, although the UK has been compliant with EU limit values in recent years. In 2010, the Committee on the Medical Effects of Air Pollutants (COMEAP) produced a report on the mortality effects of long-term exposure to particulate air pollution in the United Kingdom. COMEAP estimated that the long-term impact of particulate pollution in the UK equated to 340,000 years of life lost [16].

Recent research commissioned by Public Health England has found that the health and social care costs of air pollution (PM2.5 and NO2) in England could reach £5.3 billion (6.67 billion US dollars) by 2035. This is a cumulative cost for diseases which have a strong association with air pollution: coronary heart disease; stroke; lung cancer; and childhood asthma. When diseases with weaker evidence of association are also added, including chronic obstructive pulmonary disease; diabetes, low birth weight, lung cancer, and dementia, the costs could reach £18.6 billion (23.42 billion US dollar) by 2035. When all diseases are included, air pollution is expected to cause 2.4 million new cases of disease in England between now and 2035. PM2.5 alone could be responsible for around 350,000 cases of coronary heart disease and 44,000 cases of lung cancer in England over that time. Even small changes can make a big difference, just a 1µg/m3 reduction in PM2.5 concentrations in 2020 could prevent 50,000 new cases of coronary heart disease and 9,000 new cases of asthma by 2035 [17] Almost 2,000 locations across England, Wales and Northern Ireland have levels of air pollution that exceed safety limits, with London housing areas of the worst pollution in all of UK [18]. Many areas, including major cities like London are found to be significantly and regularly above legal and recommended levels. Air pollution in the UK is a major cause of diseases such as asthma, lung disease, stroke, and heart disease, and is estimated to cause forty thousand premature deaths each year, which is about 8.3% of deaths, while costing around £40 billion each year [19, 20].

Traffic related pollution is stated to be the main cause for this pollution, hence it is always levels of NO2, the noxious gas that is detrimental to health that are at unprecedented levels. Air pollution is responsible for an estimated 64,000 early deaths a year in the UK, of which about three-quarters are due to particulate pollution [21].

One study states that brake dust produces more of the most harmful kind of air pollution than vehicle exhausts. These tiny particles measure less than 2.5 thousandths of a millimetre across, less than one thirtieth the width of a human hair. They can reach deep into the heart, lungs and bloodstream causing asthma, heart disease, lung cancer and strokes. They can cause inflammation and weaken the body's immune system [21].

2 INTRODUCTION

Manchester and Glasgow have been revealed as Britain's drive-thru capitals [22]. New figures show both cities have 48 drive-thru outlets, the highest numbers in the UK, with McDonald's and KFC being the most popular fast-food restaurants. Birmingham has the third most drive-thru branches with 41, followed by Liverpool at 37.

There's overwhelming evidence that vehicular air pollution has a significant impact on human health. It's been shown to cause a number of respiratory conditions, such as pneumonia, bronchitis and asthma. And recently, it's even been linked to dementia, cognitive decline and delayed lung development in children. Not only that, but there's also evidence that traffic-related air pollution causes greater adverse health effects compared to other sources [23].

This is particularly the case for diesel engine exhaust emissions, which are cancerous to humans, a special concern in Europe as 42.5% of registered vehicles are diesel (compared to only 4% in the US). While commuting, people may spend one to two hours a day being exposed to diesel emissions. These levels of exposure are even higher for people who are required to drive as part of their job [23].

A study [24] recently investigated how much air pollution professional drivers are exposed to. They measured the pollution levels experienced by 141 professional drivers from different sectors, including taxis, trucks, waste removal and emergency services drivers, in London for a continuous 96-hour period. The study found that professional drivers were exposed to four times higher pollution levels when driving than when at home with exposures around 4.1 micrograms of black carbon per cubic metre of air (4.1 $\mu g/m^3$). While this amount may sound low, studies have found significant respiratory health effects, such as asthma and impaired lung function, with changes in black carbon exposure for values as small as 1 $\mu g/m^3$.

There are over 1-million professional drivers in the UK alone. Despite knowing how harmful high levels of pollution can be to human health, there have been very few studies looking at the risks professional drivers face. And, contrary to popular belief, being inside a vehicle does not protect the passengers from the emissions outside. In fact, it can lead to the rapid accumulation of air pollutants within the vehicle. This was observed as drivers moved across London, with levels of pollution inside the vehicle often exceeding 100 $\mu g/m^3$ [23].

There is no study to the best of our knowledge that assesses the exposure of drive thru employees to the amount of NO2 and particulate matter exposure due to vehicles in the UK or overseas. This study is intended to collect data about levels of various contaminants around various drive through locations in the UK and compare the levels to permissible levels in the UK. The study also investigates the different collected contamination levels during various meal times such as breakfast, lunch and dinner which would give an indication of the most contaminated period of times across the various locations investigated.

3 METHODS

In this study, air pollution in 10 locations in the UK were measured using AQMesh for two weeks of continuous monitoring for pollutants PM2.5, PM10 and NO2. AQMesh is a small-sensor air quality monitoring system for measuring outdoor and indoor air quality, offering real-time localized air quality information and data analysis. It measures gases such as NO, NO2, NOx, O3 using the latest generation of electrochemical sensors and measures particulates including PM1, PM2.5 and PM10 with a light-scattering optical particle counter. AQ Mesh supports wireless communications and all the data monitored is stored on a secure online cloud. Data is then accessed via a dashboard at chosen intervals and in the field accuracy against reference equipment.

The AQMesh combo monitors were mounted on a vehicle and placed close to the outlets where the employees are potentially exposed to the pollution emanating from vehicles as shown in Figure 1. The monitors had continuous monitoring and recorded levels of pollution at 15-minute intervals for a continuous period of two weeks.

Fig. 1. Sampling setup at different locations

The investigated locations across the UK were:

- Birmingham
- Milton Keynes
- Erith
- Taunton
- Liverpool
- Hartlepool
- Nottinghamshire
- Hull
- Newport
- Glasgow

The drive-through locations included six McDonald locations, 2 KFC locations, 1 Costa and 1 Burger King buildings. The air monitoring was carried out between August 2018 and April 2019.

4 RESULTS

The average and maximum collected samples in µg/m3 for NO2, PM10, and PM2.5 per location are shown in Table 2. The number of incidents when the concentration crossed the allowable exposure limit for each contaminant is shown in the table, as well. Table 2 also shows the percentage when the limit was exceeded to the total number of samples collected which would give an indication of exceedance severity per location.

Table 2. Pollutant levels average, maximum, incidents when limit was exceeded and percentage of exceedances per total collected

				NO2	PM10	PM2.5
Location Information				µg/m3	µg/m3	µg/m3
#	Index	Franchise	Allowable Exposure limit	40	50	25
1	Birmingham	McDonalds	Average	31.69	15.00	6.93
			Max	90.43	1138.9	135.77
			Incidents when limit was exceeded	144	12	17
			Percent # exceedances per total collected	19%	2%	2%
2	Milton Keyn	McDonalds	Average	32.0	11.4	5.4
			Max	115.3	34.8	23.0
			Incidents when limit was exceeded	63	0	0
			Percent # exceedances per total collected	19%	0%	0%
3	Erith	McDonalds	Average	50.4	22.2	12.0
			Max	182.2	438.4	153.9
			Incidents when limit was exceeded	831	123	165
			Percent # exceedances per total collected	61%	9%	12%
6	Taunton	McDonalds	Average	34.6	38.3	19.8
			Max	223.7	760.4	148.5
			Incidents when limit was exceeded	447	289	390
			Percent # exceedances per total collected	33%	22%	29%
7	ttingham	McDonalds	Average	0.0	28.2	13.2
			Max	0.0	177.5	70.4
			Incidents when limit was exceeded	0	36	40
			Percent # exceedances per total collected	0%	15%	17%
9	Newport	McDonalds	Average	29.1	24.0	14.4
			Max	597.8	128.7	85.4
			Incidents when limit was exceeded	185	92	161
			Percent # exceedances per total collected	14%	7%	13%

4	Taunton	COSTA	Average	32.3	25.7	12.6
			Max	650.6	332.7	130.3
			Incidents when limit was exceeded	286	104	157
			Percent # exceedances per total collected	21%	8%	12%
5	Liv	KF	Average	30.0	21.6	13.4
			Max	137.0	408.7	279.4
			Incidents when limit was exceeded	241	129	172
			Percent # exceedances per total collected	18%	9%	13%
10	Glasgow	KFC	Average	32.9	24.9	15.0
			Max	159.2	123.6	64.8
			Incidents when limit was exceeded	325	73	186
			Percent # exceedances per total collected	24%	5%	14%
8	Hull	Burger King	Average	33.2	20.9	10.8
			Max	61.2	64.9	33.5
			Incidents when limit was exceeded	4	1	2
			Percent # exceedances per total collected	27%	7%	13%

5 DISCUSSION

The total number of occurrences when permissible limits of exposure for each of the sampled contaminants as set by the UK standards were exceeded are summarized in Table 3. For comparison reasons and analysis, the number of incidents when the exposure limits were exceeded were scaled or normalized versus the total number of samples for each contaminant per location as shown in Figure 2. In most location, the normalized or scaled NO and NO2 has the highest occurrences compared for particulates PM2.5 and PM10. McDonalds at Erith had the highest percentage of exceedances at 61% of the total samples collected. The McDonalds at Taunton had exceeding levels at 33% and Burger King in Hull at 27%. However, since the frequency of collection differed from one location to another from 15 minutes, to 1 hr and every 4-hours for Burker King (BK), the scaled parameters was not the best tool to use for comparison.

			# Occurances when limit was exceeded		
			_NO2_Scaled	_PM10_Scaled	_PM2.5_Scaled
Location Information			µg/m3 for 1-hr mean	µg/m3	µg/m3
#	Index	Franchise	40	50	25
1		McDonalds 1	144	12	17
2		McDonalds 2	63	0	0
3		McDonalds 3	831	123	165
6		McDonalds 6	447	289	390
7		McDonalds 7	0	36	40
9		McDonalds 9	185	92	161
4		COSTA	286	104	157
5		KFC 5	241	129	172
10		KFC 10	325	73	186
8		Burger King	4	1	2

Table 3. Number of occurrences when limits were exceeded

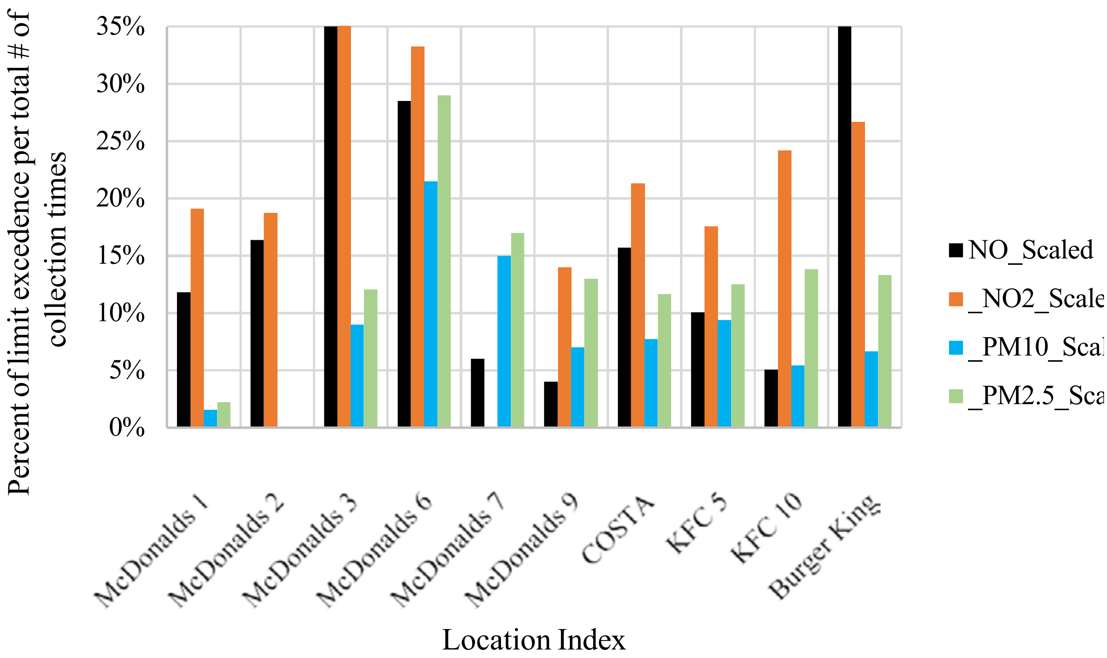

Fig. 2. Percent frequency of exceedances scaled w.r.t total number of collections per location

A more reasonable analysis was to consider the exposure limits and exceedances during various meal times throughout the day. Thus, the data was sorted and grouped in three different groups. The first one represented breakfast, for collections done during 6:00 am – 9:00 am, the second for lunch from 11:00 am – 2:00 pm and the third from 4:00 pm to 7:00 pm and represented dinner. Figures 3 through 6 show the number of samples when the limit for NO, NO2, PM10 and PM2.5 was exceeded per each meal.

The percentage of exceedances per collection frequency for each of the 4-considered pollutants showed that:

- PM2.5 and PM10 percentage occurrences were dominant during breakfast periods
- NO2 percentage occurrences were highest during breakfast and dinner times with higher values during dinner times.
- For NO, it was mixed with no exact domination of one mealtime period over the other.

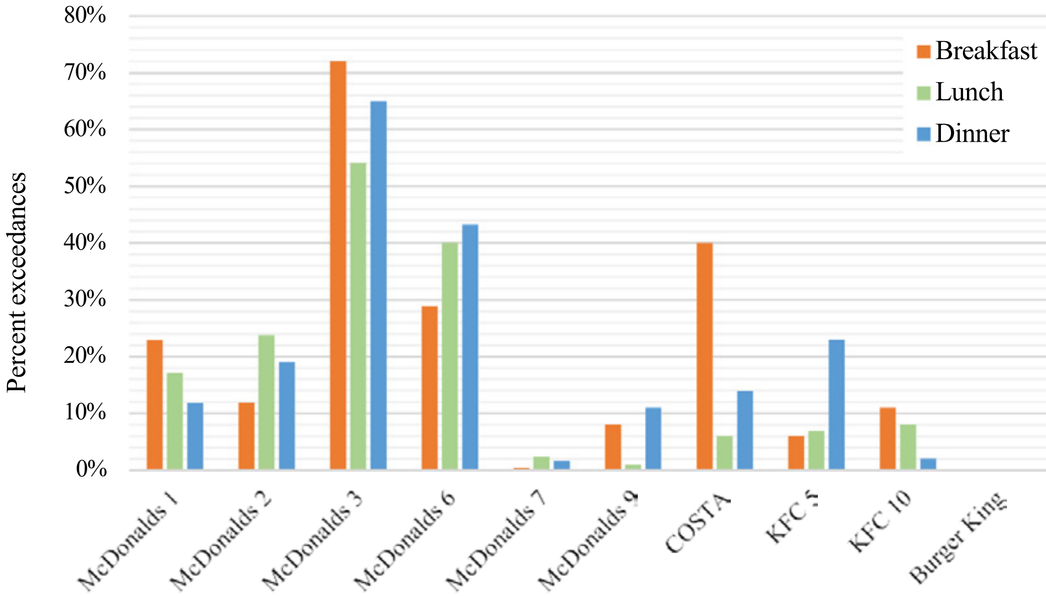

Fig. 3. Percentage of NO samples exceedances w.r.t permissible limit per total number of samples collected during each meal

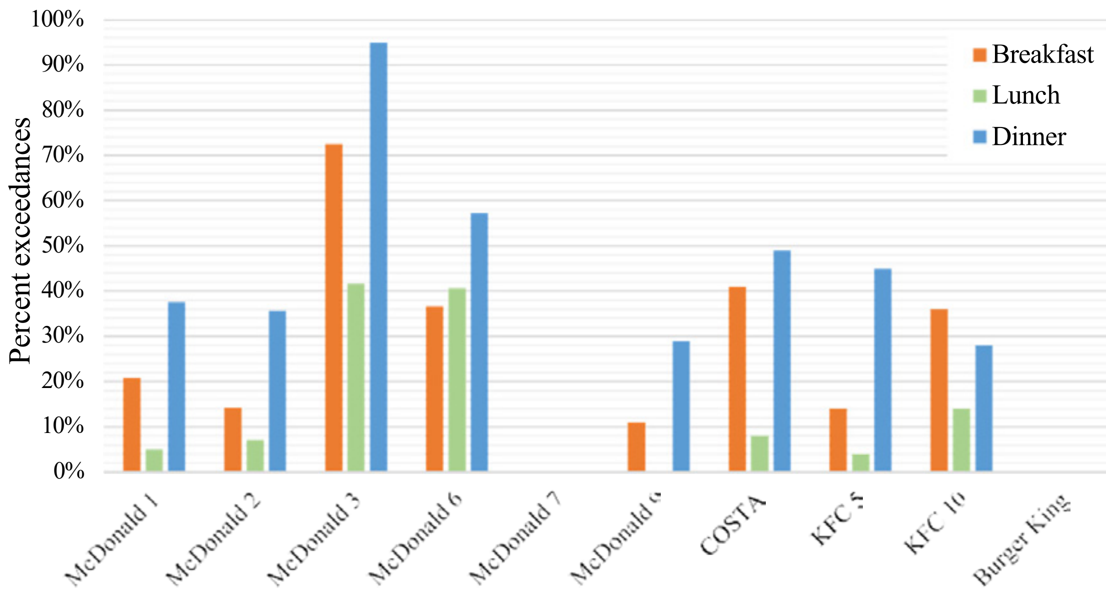

Fig. 4. Percent exceedances for NO2 per collection frequency during each mealtime

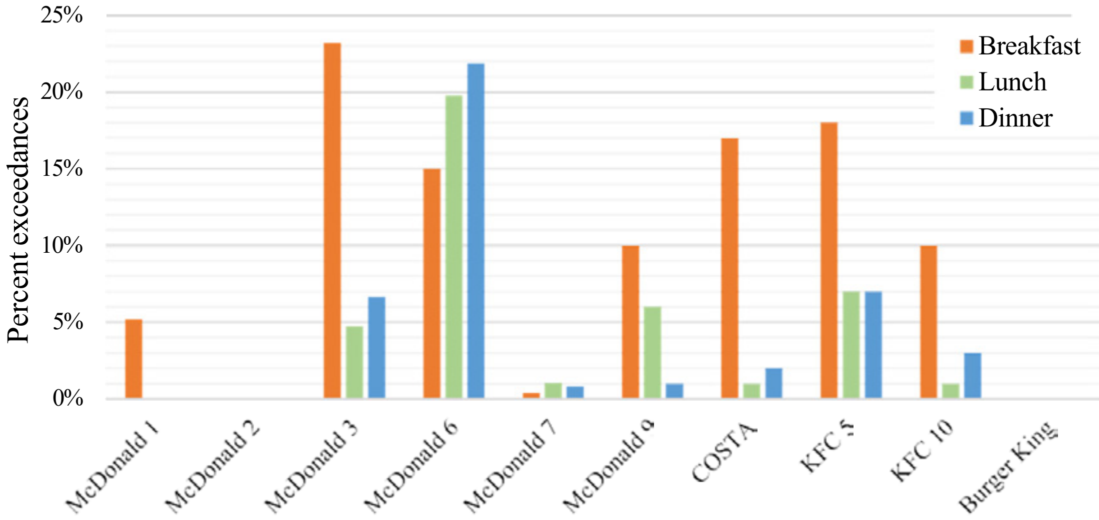

Fig. 5. Percent exceedances for PM10 per collection times during each mealtime

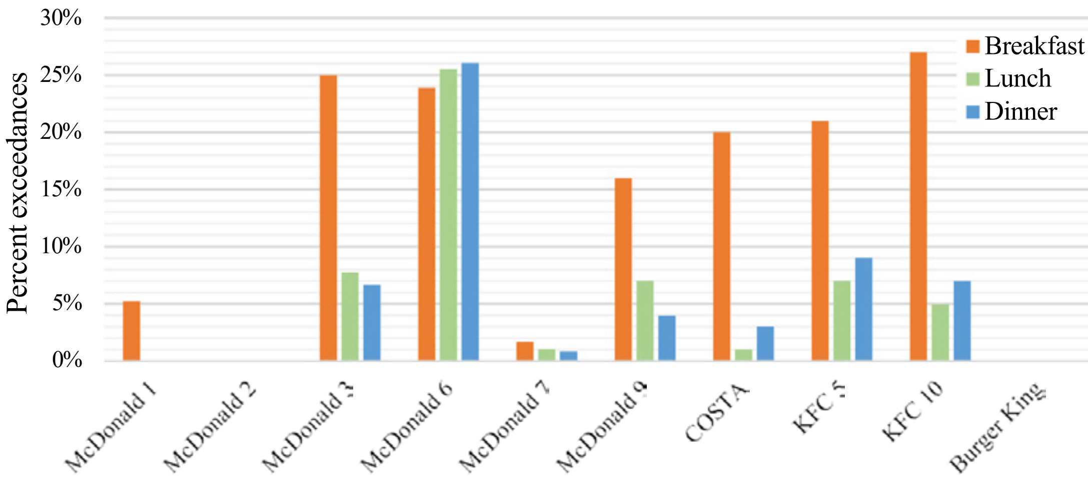

Fig. 6. Percent exceedances for PM2.5 per collection times during each mealtime

CONCLUSIONS

Air pollution is one of the leading causes of mortality and claims of thousands of lives every year. Vehicular pollution causes the most hazards to human health and affects wellbeing. There have been extensive studies that have correlated deleterious effects on health of persons living near busy or main roads. Health effects not only include respiratory illnesses, asthma, lung disorders but also hypertension and CVDs.

Although there is some limited literature on effects of pollution on outdoor workers, no study has evaluated the effects of pollution on drive thru employees and users. As vehicular pollution produces the highest levels of NO2 and PM that is considered very harmful to health, it becomes imperative to understand how this affects the drive thru employees who are subject to inhaling this pollution over short-term periods or even long-terms.

Employers have the duty to protect the drive thru employees from the harmful effects of pollution and hence provide them with the right information and awareness. Proper precautionary measures have to be employed to minimize exposure and hence mitigate any possible damage to health and well-being. The knowledge and awareness of the population also has to be enhanced by more education. Government has to provide more measures of information dissemination to the public that will enable the adoption of positive behaviors to support pro-environmental actions.

Employers have the primary responsibility for protecting the safety and health of their workers. Employees are responsible for following the safe work practices of their employers. Keep the drive-thru window closed as much as possible to limit exposure to automobile exhaust. Employers have the primary responsibility for protecting the safety and health of their workers. Employees are responsible for following the safe work practices of their employers.

In this study, AQMesh monitors were mounted onto the back of vans and parked near the drive thru outlets of 10 locations across the UK. Pollution levels were constantly monitored for two weeks. The total number of exceedances of the pollution were calculated against the standard pollution levels. The number of vehicles passing through each outlet was not recorded which would have enabled producing models of exposure. Further research will also be required to calculate the proximity to main roads, other traffic nearby although not necessarily passing through the drive through, the wind direction etc. This study serves as a preliminary source for pollution levels around various drive-thru locations in the UK. Further studies would be needed to replicate and confirm such results and help put regulatory policies and actions.

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DEVELOPMENT OF A SMART CLAMPING CONTROL FOR MILLING MACHINES

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ABSTRACT

The smart clamping control should work independently as a "second pair of eyes" and thus make a significant contribution to avoid serious collisions and the resulting high repair and failure costs. To implement the smart clamping control, the type of clamp must be determined and the blank measured. The goal was to develop a system that optically records the real clamping situation in a CNC milling machine, compares it with the specification, detects deviations and warns the machine operator of possible collisions. To realize the system you can use analytical feature based methods or Convolutional Neural Networks a machine learning method. The proposed solution is a trade-off between analytical computer vision and deep learning. We describe which problems arose during implementation and how we solved them. A special difficulty was to design the clamping control to be compatible with the DATRON NEO CNC milling machine.

Keywords: Computer Vision · Smart Human Computer Interaction · Convolutional Neural Network · Smart Application

1 INTRODUCTION

There is currently no service function for the DATRON NEO [1] that decides whether the size of the blank is compatible with the selected milling program or not. If the selected blank is too large, the spindle and the blank may collide during the milling process. Such a collision can cause damage of more than € 10,000 and cause the machine to stand still for hours or days. If the selected blank is too small, the corresponding workpiece cannot be produced. The task of the smart clamping control is to measure the blank as precisely as possible using a computer vision system. If the dimensions determined by the computer vision system do not correspond to the specifications of the selected milling program, the worker should be warned. The milling machine operator should decide how to deal with the warning.

Although the smart clamping control is not yet fully automated, the use of clamping control promises significant advantages for production. A few years ago large series production was still the rule, today it is increasingly small batches that are produced. Frequent retooling of the machine is the result, and this also increases the frequency of setup errors. The smart clamping control should make it possible to detect and avoid set-up errors in the future.

2 TASKS OF THE SMART CLAMPING CONTROL

To detect set-up errors, the smart clamping control must measure the blank with a maximum deviation of 0.02 to 0.05 mm. If a clamp is used to fix the blank rather than a vacuum plate, the type, the position and the orientation of the clamp must be recognized. Because even an incorrectly selected clamp can lead to collisions with the spindle. To be economical the standard camera, which is already built into the DATRON NEO, should be used for the smart clamping control. This is a camera comparable to a standard webcam with a resolution of 1920x1080 pixels. The camera with a fixed focal length is fixed at a constant height in the milling space. A movement of the camera in the plane is possible because it is attached to the spindle.

3 CONCEPTION OF THE COMPUTER VISION SYSTEM

Currently Convolutional Neural Networks (ConvNets) are the favorite choice to detect different objects. There are multiple reasons for the use of ConvNets. The most important reason is the ability to recognize objects that cannot be clearly described by characteristic features [2]. The clamps are a good example for that. A clamp usually has two jaws to hold an object in place. However, some clamps have more than two jaws and others have none. They all have different shapes, sizes and labeling. Thus, it is very difficult to find rules that describe what an image must look like, if a clamp is shown on it. It is easier and more effective to use pictures that show clamps of different types and to train a ConvNet with it.

If the task is to recognize clamps, using ConvNet might be a good decision. It is not a good decision if the goal is to recognize blanks. Blanks have a clear structure. Usually they are cuboid. Furthermore, the lighting in the milling room can be regulated to minimize lighting problems. Under these conditions, traditional, analytical computer vision methods, like threshold procedure, edge and corner detection, are better suited for measuring the blanks than ConvNet. Huang et al. took a similar approach for workpiece recognition [3]. To be able to use the computer vision system productively, the measuring accuracy in case of the blanks must have a tolerance of 0.02 to 0.05 mm.

4 PROTOTYPE IMPLEMENTATION OF THE COMPUTER VISION SYSTEM

To be able to implement the smart clamping control, we must recognize and measure the fixed blank. If the blank is not fixed by the vacuum plate, the type, position and orientation of the clamp must also be recognized by the Computer Vision System.

4.1 MEASURING THE BLANKS USING CLASSICAL, ANALYTICAL COMPUTER VISION

At the beginning, a blank usually has the shape of a cuboid. Since the camera takes pictures from above in the setup of the milling machine, only four corners are visible. We can adjust the lighting situation by using polarization filters so that there is as little variance as possible. However, we cannot completely prevent highlights and reflections. Another difficulty is that the blanks are made of different materials such as aluminum, steel, etc. Most of the materials are highly reflective, which makes it difficult to recognize the objects. The materials are subjected to different manufacturing and cutting processes, which affects the appearance of the surface of the blanks.

To recognize the position of the blank, the user must tap the blank on the touchpad. The computer vision system uses the values of the tapped pixels to determine the position of the blank in the picture. The rough measurement of the length and width of the blank is done by recording two camera images, slightly shifted in the plane, from a camera equipped with a wide-angle lens (overview camera). The height of the blank is determined by using a calibration object. Since the resolution of the camera is too low for our application purpose, we do not get the necessary accuracy in the measurement. To increase the resolution, we use an identical second camera without a wide-angle lens (see Figure 1) for detailed shots.

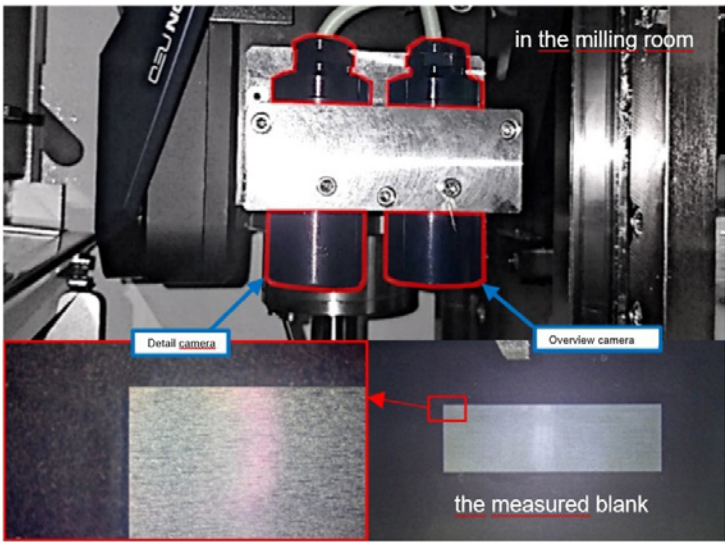

Fig. 1. Setup for blank detection: In the picture above, you can see the detail camera on the left and the camera with the wide-angle lens on the right, which can record almost the entire milling interior. Below, on the left you can see the picture of the detailed camera and on the right the picture of the overview camera. It shows the entire blank.

The detail camera is positioned so that it can record the corners of the blank. Using the position of the detail camera and the travel path, we can measure the blanks with the desired accuracy.

4.2 RECOGNIZING THE TYPE OF CLAMP AND ITS POSITION AND ORIENTATION

The analytical method has the advantage that it works with pixel precision and does not require any training images. The creation of training images is a lengthy and labor-intensive process. If the user uses a clamp for fixation and not the vacuum plate, the type of the used clamp must also be recognized. Too large a clamp can lead to collisions with the spindle and too small a clamp does not offer the necessary stability during the milling process. All clamps look similar, but not the same. It is difficult to find unambiguous rules that clearly describe a clamp. Because of this variance, it made sense to recognize the clamps using Convolutional Neural Nets. We used YOLO [4] for initial tests. The network was retrained with transfer learning. We use specially made training images for this.

Unfortunately, the attempts were not a resounding success. Difficulties are caused by the types of clamps that do not differ from one another except for very few details (figure 3).

Fig. 3. Two similar clamps

The fact that the camera currently installed in the milling machine only look at the clamping devices from above had an extremely negative effect. This means that fewer optical features can be used to differentiate between the clamping devices. So, it is hardly surprising that the validation of the Lang 48160-77 clamp only achieved an accuracy of 32% in the detection of this clamping device (figure 4). Other clamping devices were recognized even worse.

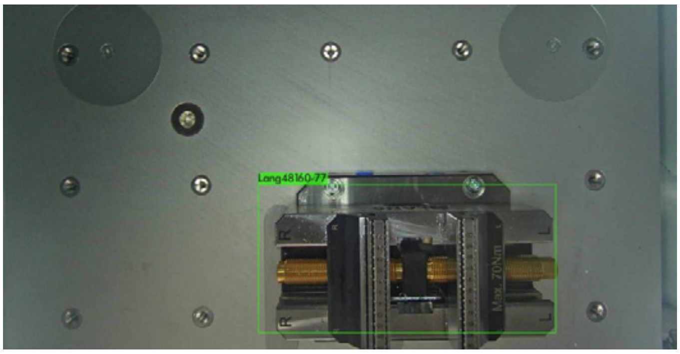

Fig. 4. The detection of a special clamp with YOLO V4

Another difficulty is that a blank clamped in the clamp can cover large parts of the clamp. As a result, other typical features of the clamp are covered, which further restricts the options for optical differentiation through a ConvNet. To differentiate the clamps, the clamps would not only have to be picked up from above but from different perspectives. There is currently no way to implement this in the milling machine.

To be able to distinguish the clamps already today, a concept for marking the clamps with a QR code was developed. The code can be used to identify the type, position and orientation of the clamp. Since the clamps offer little space to attach the QR codes, the code is often very small and cannot be read due to the insufficient resolution of the overview camera. The idea is to use YOLO to recognize the approximate position of the QR code. If the code cannot be read, we need a second step. In this step the detail camera approached the code and take a higher resolution picture.

5 CONCLUSIONS FROM THE SMART CLAMPING CONTROL PROJECT

The Smart Clamping Control project has shown that convolutional neural networks (ConvNets) offer the possibility of localizing objects such as clamps and QR codes. However, a precise differentiation of the different types of the clamps, was not successful. In the production process, however, the localization of objects can already help to optimize the work process. A ConvNet could, for example, replace the interaction at the beginning of the milling process in which the blank must be marked by the user.

For precise measurement, the classic computer vision methods based on analytical calculations have proven themselves, since the desired accuracy can only be achieved with pixel-precise image evaluation. We are currently increasing the resolution of the recording by using a detail camera. Initial experiments show that it is possible to increase the resolution using Autoencoders.

6 OUTLOOK: SUPER RESOLUTION TO REPLACE THE DETAIL CAMERA

Furthermore, first attempts were made with Autoencoders. The aim was to train the Autoencoder in such a way that it reconstructs less well-resolved images in greater detail. The tests were carried out with the HighRes-net[5][6]. This multi-image superresolution network uses several image recordings from slightly shifted recording angles to calculate the image with a higher resolution. The aim is to evaluate recordings from the overview camera of blanks and clamps using the Autoencoder without having to resort to the detail camera. In the project, the first tests were carried out with recordings of blanks, which are optimistic. By using the detail camera, the resolution of the recordings can be increased by a factor of 10. The usual scaling factors of super resolution networks are between 2 and 4, rarely 8. The network used here scaled with a factor of 3.

With the help of an Autoencoder, the recordings of the overview camera could in future be improved to such an extent that an additional detailed camera is no longer necessary. The difficulty with using Autoencoders, as with the ConvNets, lies in the creation of the appropriate training data.

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6. HighRes-net, https://github.com/ElementAI/HighRes-net Combination of CFD visualization and Mixed Reality environments for Fluid Power instruction

COMBINATION OF CFD VISUALIZATION AND MIXED REALITY ENVIRONMENTS FOR FLUID POWER INSTRUCTION

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ABSTRACT

Designing a learning space poses challenges; one of them is to engage students while imparting knowledge in classrooms. In laboratories, these spaces must provide a practical experience. A hands-on experience is a mechanism to promote understanding new concepts interactively. For example, when it comes to fluid power concepts, the most effective way to learn about this field is through physical interaction with real-life applications. However, virtual learning environments are also an alternative to provide students with a hands-on experience for real-life applications. These kinds of environments are not limited to increased safety or the reduction in the cost of instrumentation needs, but they extend to the increased intuitiveness of the virtual environment interface and the increased special awareness of the students. To overcome limitations inherent to physical approaches, this study developed a fully immersive and interactive Mixed Reality (MR)/ Virtual Reality (VR) laboratory for fluid power instruction. Most importantly, this document provides a thorough methodology to create the virtual environment. Where HoloLens 2, mixed reality smart glasses, are used to showcase the laboratory.

Moreover, this work includes computational fluid dynamics to visualize the interaction of the fluid with hydraulic components in operation. In this MR laboratory, students will move around through different tasks, assemble a hydraulic component, identify the gear pump parts, and perform measurements when given a CFD animation. Additionally, the laboratory describes how to integrate the different technologies to create the virtual environment. Finally, the perception of the virtual laboratories for fluid power classes was measured, where knowledge acquisition, comfort level, and potential improvement are key indicators were assessed through a survey. More than 70 percent of students consider a Mixed Reality laboratory a viable approach for fluid power instruction.

Keywords: Learning Space, Mixed Reality, Fluid Simulation.

1 INTRODUCTION

Sample Heading (Forth Level). The contribution should contain no more than four levels part of the instructors' labor is to innovate, bring new interactive activities to the classroom, and, most importantly, keep up with recent technological advances. Instructors developed new pedagogical strategies to deal with this situation in response to the global pandemic. They moved from in-person classes to virtual ones. Moreover, this restriction made it impossible to access laboratories and conduct some experiments through them. This situation sparked the development of virtual learning spaces, leading institutions to rethink how the activities for instruction are imparted. In this new approach, it is necessary to keep a hands-on experience as part of the learning process, especially in some disciplines such as fluid power (scope of this research). The value of learning resides in the hands-on practices the students perform.

However, a virtual laboratory leaves out the physical interaction with the different mechanic parts. Traditionally, the tools to teach hydraulic and pneumatic systems build upon components or computer simulation packages that emulate a real hydraulic or pneumatic system. Both teaching methods trust in the availability of the equipment (components) or computer licenses to build systems. Many training stations have been developed for instruction in fluid power courses. The stations enable different practices, from observing how the pressure builds up in the system to modeling flow through an orifice, and in some cases, including the control system.

Yet, teardown and reassembly are the most valuable and effective methods for teaching about the elements [1]. However, fluid power systems are often too large to properly fit within engineering labs due to a lack of space in science laboratories and the cost of acquiring these materials [2]. More specifically, fluid power education has been hindered by the lack of student access to laboratory experiments [3]. Some companies design fluid power training equipment for instruction in academic or industrial environments. These companies include Parker Hannifin, Eaton, Bosch-Rexroth, FTPI, Festo, Hytech, FTPI, and Amatrol [4]. Most of these trainers can be customized. Nevertheless, once the trainer is configured, the modules taught are limited to the specific components available on the trainer, and these trainers are costly.

The problem being addressed is the need for an alternative hands-on method for fluid power instruction. This is an issue due to fluid power components' bulky and expensive nature and the time consumption needed for system setups. Limited classroom space and safety concerns of students add additional limitations to current instructional methods. An alternative hands-on interactive approach must be available that does not neglect traditional methods' practice.

Moreover, when comparing the virtual and physical approaches, there are pros and cons. A standard error is to believe that only one of them can be implemented in classrooms. When in fact, a combination of these two can also be favorable for students. As in the case of mixed reality, a technology that has been increasing and opening a wide range of opportunities in different fields (educational, enterprise, etc.)

Bringing mixed reality into the classroom is an alternative to bringing together the best of both approaches. Besides, it has been found that it "increases motivation interest in students [and] promotes the acquisition of investigative skills" [5]. According to a study done on student perception of mixed reality, "the younger the students are, the more likely they will desire to use MR [mixed reality] in higher education" Willocks [6]. Another study focused on improving construction and engineering students' skills by implementing mixed reality as a form of hands-on instruction and later testing the students on skills learned [7]. Results of the study performed by Wu et al [7] were not collected at the time of the study's publication; however, it remains significant to this study due to its detailed outline of methods used and illustration of how involved mixed reality lessons can prove to be. Accordingly, this study combines mixed reality technology and fluid power field to fill the gap between them and transmit the knowledge to students well-provenly.

Other than the viability of mixed reality in classrooms. Some cases of success in companies are reported by Festo [8]. They have a training program where MR assists in the assembling process of pneumatic circuits and more complex systems. This company also claims that its computer-aided system prevents users from life-threatening or hazardous situations (environment and machinery). To reproduce an experience close to real-life situations, they created CIRO VR, a software that provides a real-time result for 3D simulation.

Other companies, such as Bosch, are also pioneers in this area. They use MR to conduct maintenance programs remotely, such as those reported by Neges et al. [9]. As a result, workers can execute hands-on tasks without using physical manuals or guides. Furthermore, Bosch points out that mixed reality is a promising tool, which enables an immersive interactive environment, where training within a company is carried out at a low cost, and safely [10].

In addition to MR applications for enterprises, universities also consider that there is an excellent value in MR [11]. Classrooms are moving to a part-virtual laboratory environment where old-fashioned lectures have been left behind [2]. [17] shows how students benefit from this approach by way of illustration. Researchers have re-created a virtual civil engineering hydraulic laboratory and virtual flowmeters from scratch in this study. The research was designed to reduce the risk of interacting directly with an environmental civil engineering setting and develop an educational tool that students can help improve by providing feedback. In its final version, students accomplished the characterization of an open-channel flow.

On the other hand, in works related to fluid dynamics, having a 3D overview representation of the flow behavior can be challenging. Mixed reality serves as an immersive tool to visualize the flow and allow the user to be virtually immersed in it. This can be illustrated quickly in the studies by [12], [13], [14]. The authors simulated the thermal change process in a university room and animated it in a head-mounted device (HMD). This methodology facilitates the rapid iteration of different conditions (temperature changes and materials properties). In a fluid mechanics or fluid power classroom, the visualization process for designing a virtual lab involves several steps, from the CAD modeling of the component to the fluid simulation results in a virtual environment. Authors [15], [16] propose a workflow for the visualization process.

Integrating a CFD simulation into a mixed reality environment requires a clear workflow. It has been found in the literature that a typical workflow has four stages, design, simulation visualization, and virtual environment. The information flows between different software due to the lack of platforms to combine this technology in one. The researchers created the 3D model in a CAD modeling package (design stage), afterward, they prepared the 3D model and have it exported into a CFD software, the latter delivers multiple output formats (e.g Ensight Gold, VTK)., however, none of them are compatible with the 3D engine game platform, Unity 3D. Consequently, the numerical information passes through Paraview, where the CFD results are rendered, to finally be part of the scene designed in Unity for the virtual laboratory.

The present study aims at developing two tasks:

1. ***Provide a guide on integrating different technologies to create mixed reality laboratories oriented to complement an advanced fluid power course. This laboratory contemplates creating the elements needed to deploy a hands-on experience when teaching fluid power in the classroom. Moreover, this work aims at integrating CFD simulations***

into the virtual environment. This MR laboratory will allow for a holistic overview of how fluid flows interact with hydraulics components.

2. *Assess the level of reception of this tool in the Fluid Power class. For this purpose, students will fill out surveys to measure their knowledge about gear pumps and pressure relief valves and evaluate how they perceive this tool when using mixed reality, HoloLens 2 glasses.*

2 TOOLS FOR DEVELOPING VIRTUAL LEARNING SPACE COMPONENTS

Today, when it comes to designing learning spaces for fluid power classes, a few questions arise: What approach will be implemented, a virtual or physical space? then if choosing a virtual or mixed reality environment, the next question is, what are the suitable tools to create that learning environment? Not to mention, that there is a wide range of activities that could be performed in laboratory sessions regardless of the approach such as interactive demonstrations, case studies, etc. When the virtual approach is selected, different technologies come into play when conceiving these activities. For example, this study leverages HoloLens 2, a head-mounted device, as a tool for the visualization of hydraulic components in a mixed reality environment. Other than this technology, various software tools are also part of the designing process, Unity (game engine), Blender (3D computer graphics), and Ansys CFX (fluid simulation package). The computer software implemented in the present study falls into two different categories: modeling – physic simulation and virtual environment design, as seen in figure 1. Each software is only compatible with one output file extension. This fact leads to using Blender to convert the different output files obtained from Inventor (STL) and CFD (VTK) into a compatible one that Unity can read. A profound explanation is provided in the subsequent paragraphs.

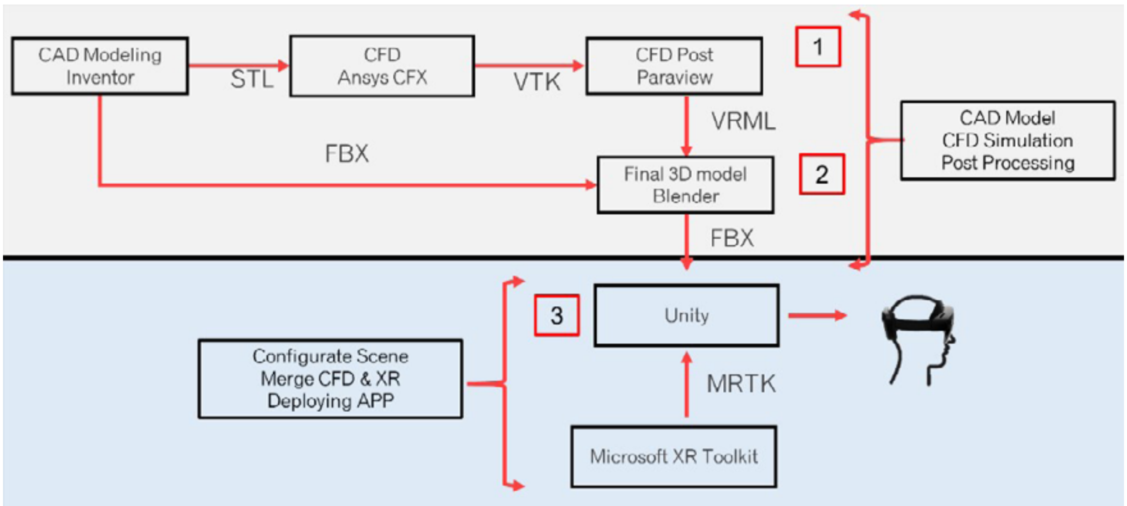

Fig. 1. Workflow to develop XR environment for HoloLens 2. Grey regions represent 3D modeling. The blue zone shows the laboratory design process and its implementation.

Modeling – physic simulation consists of preparing the 3D models for the Gear Pump and Pressure Relief valve. It is worth mentioning that this 3D model also feeds the fluid simulation process. The software used in this stage is Inventor Autodesk, the file format delivered is STL.

The fluid simulation is conducted in Ansys CFX. The methodology and the case setup are discussed in section 3. An intermediate step took place to couple the simulation with the virtual scene. The file resulting from the fluid simulation, VTK, is not compatible with Unity. Fortunately, Paraview, a software for fluid simulation visualization, renders the numerical results that can be exported into Blender. The simulation stage finishes with a combined FBX file flowing from Blender to Unity.

However, the tools used so far only cover the preparation of 3D models needed to design the hydraulic components scene in Unity. Some extra preparation work remains. For example, to exploit all the benefits of HoloLens 2, the Microsoft tool kit for mixed reality asset, MRTK, was imported into Unity. This tool not only supports the user interface's design but also equips the developer with some basic scripts to make the app more interactive. Some of these scripts allow having an exploded view of a 3D object in Unity. Other, such as the drag script, is assigned to our hydraulics components to drag a part of a hydraulic component and place it in a specific position. Also, a script helps to identify parts of the game object by placing some labels over them.

Some knowledge of the C# programming language is required. Some specialized functions such as CFD result animation, switch scenes, and machine element motion needs to be coded from scratch in Visual Studio. This latter enables the coding of new features that are not part of the MRTK.

3 DESIGN DESCRIPTION OF THE VIRTUAL LEARNING SPACE

As stated in the abovementioned section, the virtual laboratories for the hydraulics components – Gear Pump and Pressure Relief valve – approach two learning objectives: 1. Assemble part of a hydraulic component. 2. Flow characterization when a velocity and pressure field is given. This procedure is not straightforward, which implies working with separate scenes to accomplish the proposed tasks.

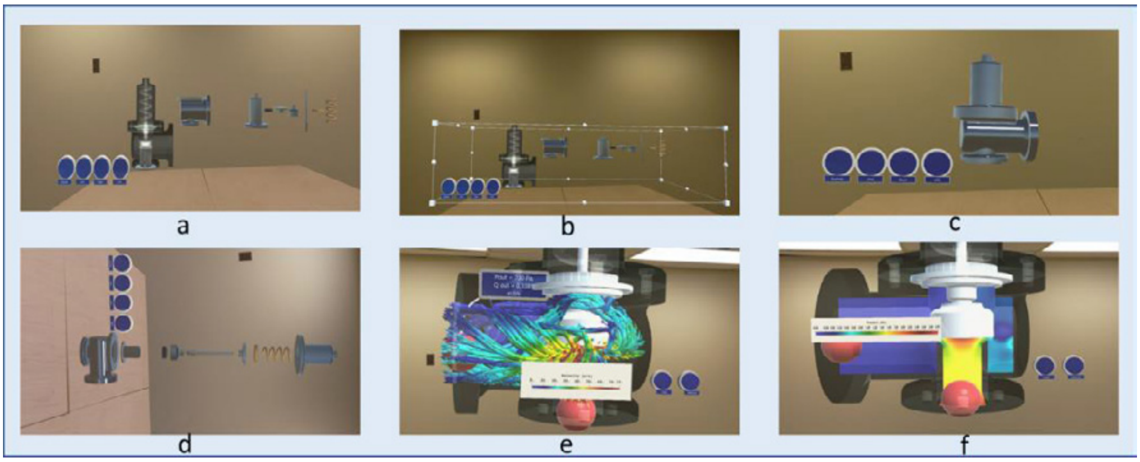

Fig. 2. Assembling process. a) repositioning and scaling of the pressure relief valve. b) Labels for each individual component. c) Pressure Relief Valve Assembled. d) exploded view and, buttons to reset the app or switch the mode. e) CFD Results, velocity profile. f) CFD Results, pressure profile.

3.1 ASSEMBLY PROCESS

The level of success of a virtual laboratory relies on how well this environment mimics expectations from a physical or real laboratory. The same principle applies to handson experience laboratories for a fluid power class. For the present study, students are provided with an exploded view of the component to assemble. Once, they identify the parts and where to place them, users are tasked with dragging the components into their respective places. What students are expected to do during a traditional laboratory session is covered by the assembly process of the two hydraulic components (Pressure Relief Valve and Gear Pump) in this virtual space.

To set the exploded view script, it is necessary to have as an input two 3D CAD models, the compact view 3D model, and an exploded version one, as shown in Figures 2.a, and 2.d. These models represent the cartesian coordinates of the hydraulic component in the virtual environment scene. The models also allow users to take a closer look at the part, identify geometric characteristics, and have a general panorama of the internal appearance of these components.

Other than alternating between different views, the 3D models used for the exploded script can be recycled to implement the drag component feature. At the beginning of the visualization, the user finds a randomized, disassembled game object, a hydraulic component. The drag script is attached to each component, relating the positions where the students are supposed to place them. Due to the drag script being part of the hydraulic component, the user can grasp the individual part and snap it into the desired position in the compact model view to obtaining the final assembly shown in figure 2. c.

As in a puzzle, it can be intuitive to recognize the position of each part of the hydraulic component. However, these positions appear in the virtual environment as a grayed-transparent part to avoid misguiding students. If the user feels confident moving around, the option to disable these hints is available, as seen in figure 2.a.

A helpful feature of this laboratory is the component labels, the name of the different parts appears when the user points to them with a finger. The student can retain the name of the parts and follow the different instructions to complete the assembly process. this script is called tooltip. Finally, a script to reposition the whole environment is placed on the user interface and each individual component. When activated, a white box enclosing the scene appears, so the user can translate, rotate, and scale this box. Any change in position and size will be reflected in the hydraulic components.

At the end of the assembling process, the user will have more than a rough idea about the parts of the hydraulic component, how they interact with each other, and most importantly, how to assemble the gear pump or pressure relief valve.

3.2 CFD PROCESS

The Naiver-Stokes (NS) equation describes the fluid dynamic behavior. Due to the complexity of the equation, none can afford to solve it by hand. Some computational packages offer an alternative. They implement a technique called the finite volume method. Which basically solves the equation by applying numerical methods. Regardless of the computational package implemented, the user of this technology is expected to provide three elements: a computational domain, initial condition, and material properties.

In our case study, a computational domain is a geometric representation of the system to analyze, in other words, a 3D model of the hydraulics components. The package takes the 3D models into a grid to solve the NS equation at each mesh point, called nodes. After preparing the 3D representation of the hydraulic components, the next step is to provide the initial conditions, which means setting the system's operating conditions. Finally, the package needs to know the material, and fluid properties, such as density, viscosity, and state (gas or liquid).

The present study uses Ansys Fluent as a computational package to solve the NS equation. It is worth mentioning that two hydraulic components are simulated, Gear Pump and Pressure Relief Valve. Figure 3 shows where the initial conditions were applied for each hydraulic component. Afterward, once the simulation converged, the simulation results are transferred into Paraview to be post-post processed.

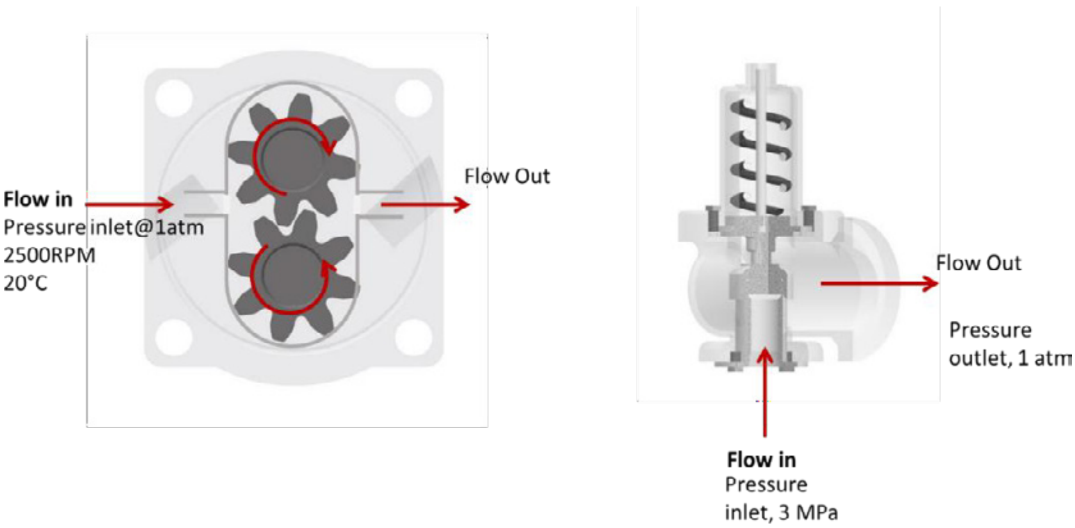

Fig. 3. Boundaries conditions for the Gear Pump and the Pressure Relief Valve

The post-processing stages lead to developing two different representations of the flow patterns. Paraview counts with several filters to represent the raw data extracted from the simulation stage. This study displays the data in two different types of visualization, contour for pressure fields, and streamlines for velocity fields. The latter is a 3D animation that represents flow patterns such as vortexes, flow paths, and low-pressure zones, see figure 4.

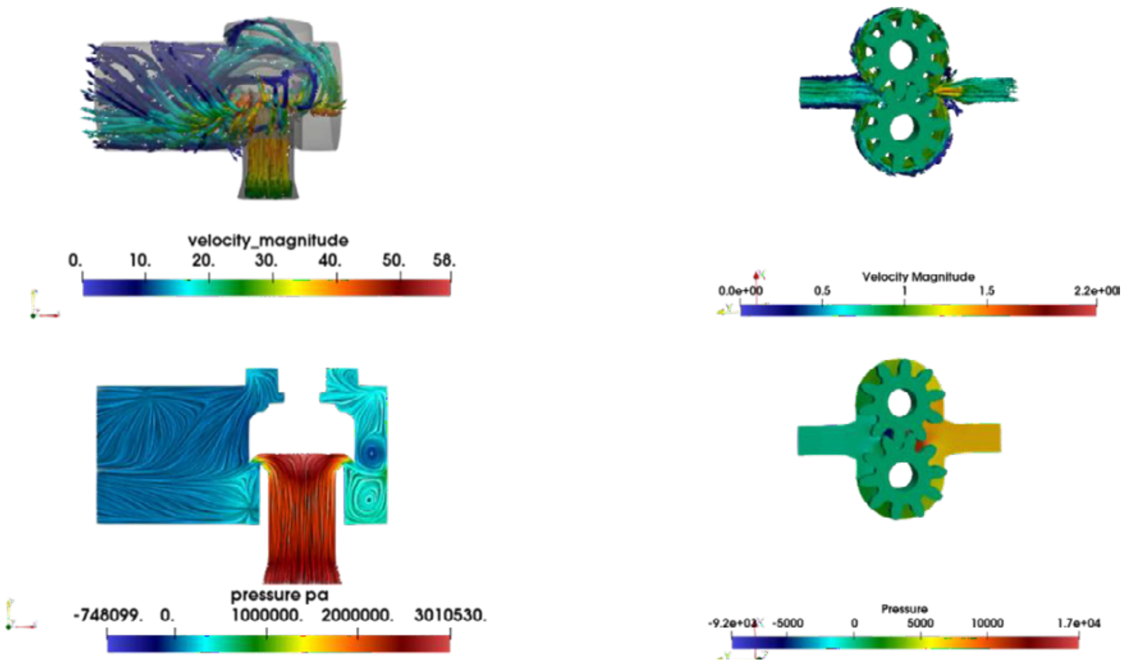

Fig. 4. Fluid flow fields a) velocity field pressure relief valve. b) pressure contour for the pressure relief valve. c) velocity field gear external pump. d)pressure contour for the gear pump.

The picture on the left shows the treatment simulation results implementing the contour and streamlines for different time steps to see the evolution of the flow not only in space but also in time. There are still a few steps before these animations are part of the whole scene deployed into HoloLens2. As mentioned in the previous section, the file format generated in Paraview is x3D. Blender received the 3D animation from Paraview, prepares the final scene, and generates the OBJ files to be exported into Unity.

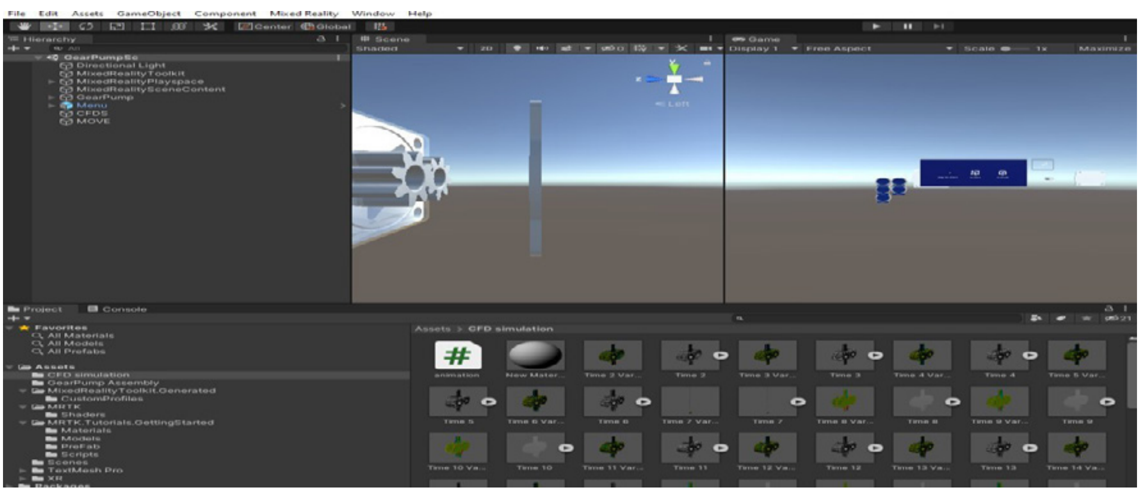

Fig. 5. render visualization for the 3D animation exported from Paraview

A drawback seen from this stage, the color map imposed on the 3D animation appears in grayscale when exported into Unity. The 3D model cannot retrieve vertex color for the mesh, figure 5. Thus, a shader material is created to color the models for the hydraulic components exported into Unity. As seen from the figure below, two models, the one in greyscale, and the copy of it, are rendered to visualize the different color maps for each fluid field. This standard procedure is repeated and applied for the pressure relief valve.

Up to this point, it has been discussed the methodology to display CFD results in Unity. However, this methodology does not give insight into how to bring these simulations to life. The dynamic animation is achieved by coding in C#. Part of the script used to animate the CFD scenes can be seen in figure 6. In an attempt to make these scenes comprehensible, a user interface allows for switching from one flow field to another, in consequence, the user can visualize the fluid flow fields in different frames.

```
// Update is called once per frame
void Update()
{
    if (Time.time >= nextTime)
    {
        if (i > 0)
        {
            Destroy(test); // destroyed the first game object
        }

        myRotation.eulerAngles = new Vector3(180, 0, 90);  // indicate the rota
        test = Instantiate(myObject[i], new Vector3(0, 0, 2.0f), myRotation); /

        if (pressure)
        {
            test.transform.Find("pressure").gameObject.SetActive(pressure); //
            pscale.transform.gameObject.SetActive(pressure);


            test.transform.Find("tubes").gameObject.SetActive(!pressure); // if
            test.transform.Find("arrows").gameObject.SetActive(!pressure);
            vscale.transform.gameObject.SetActive(!pressure);


        }
        nextTime += timeInterval; // instantiate the next game object
        i++;
        print(test);
        if (i > 20)
        {
            i = 0;
            Destroy(test); // destroy former game object
        }
    }
}
public void changeButtom()
{
    pressure = !pressure;
}
```

Fig. 6. script to animate the CFD results for the different hydraulic components in time.

For the user to characterize the fluid flow around the hydraulics components, pieces of information, in the form of labels, are placed in the scene, as shown in previous figures, figures 2.d and 2.e. The student will conduct simple calculations such as hydraulic power, flow rates, and pressure drops.

Demo for the virtual laboratory deployed on HoloLens 2.

4 FEEDBACK FROM THE USER PERSPECTIVE

The proposed laboratory was implemented in the advanced fluid power class, a thirdyear class. However, this fact does not mean that the laboratory fits into only that category. From the implementation, this study seeks to contrast the students' previous knowledge about pressure relief valves, evaluate the experience using mixed reality technology, and finally measure the knowledge acquired according to what was projected in the laboratory. The assessment process is broken down into three parts. Pre–survey, laboratory experience, and post-survey.

In this study, students were asked to answer questions based on any previous experience with virtual/mixed reality and their perception of its effectiveness as an educational tool. This part was addressed through the pre-survey in the first laboratory. After the implementation of this laboratory, analysis of the laboratory responses will be carried out using a similar method to previous mixed reality research [17].

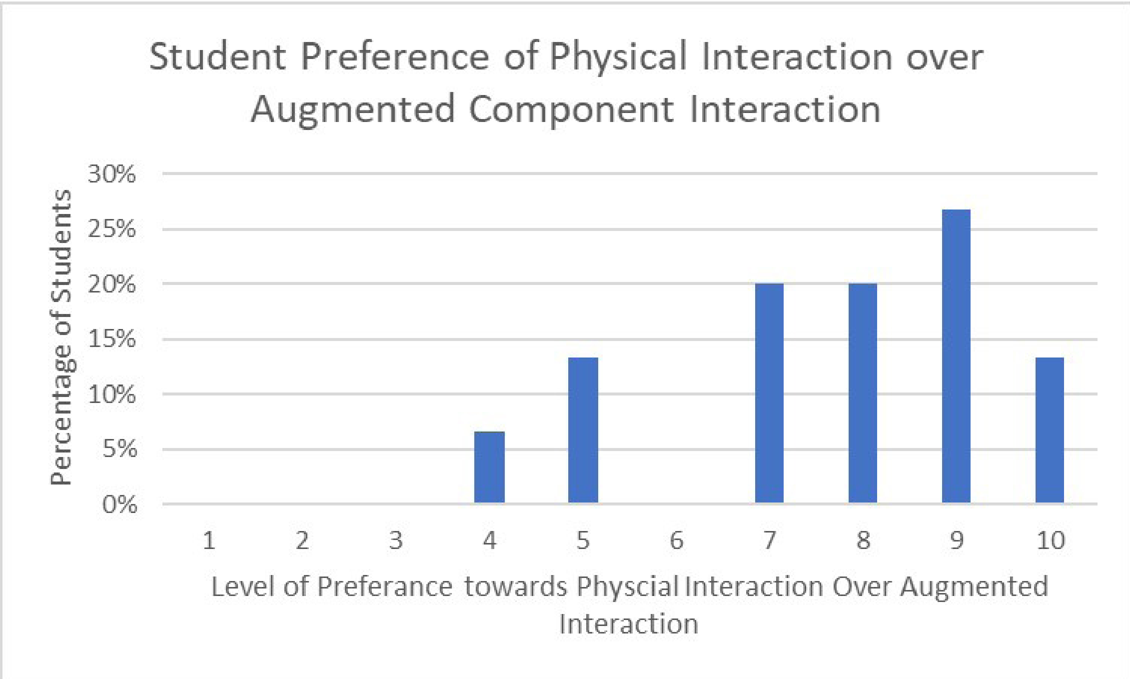

Fig. 7. pre-survey results for student preference towards physical interaction of components vs augmented interaction of components.

15 participants filled out the survey. When asked about their preferences for physical interaction with components vs. an augmented interaction, 90% of responses fell into the 70 – 100% preference for the use of XR in the laboratory, as shown in figure 7. From the same pre-survey, it can be highlighted that using XR in fluid power instruction is well received.

Moreover, students indicated that their previous experiences with extended reality are minimal, with an average experience of 3.80/10, as results collected from the survey (see figure 8). However, this lack of knowledge can be channeled positively. Past research has shown that students with unsignificant exposure to XR have benefitted more from XR in education than students with higher levels of past XR experience.

Fig. 8. pre – survey previous exposure level to Extended Reality.

This study had students fill out a postquestionary to improve student experience when using XR devices. The results collected from this question fit into six categories – space restriction, sickness, communication among HoloLens 2, pre-training, and more interactivity-. The main struggle was the lack of detailed training on how to use the HoloLens2. Forty percent of the students expressed difficulties trying to familiarize themself with the interface and the gesture to move the components around. Others (21%) expressed some concerns about interactivity.

For the second question, the students were asked about how this lab could meet their needs as students. It was found that 50 percent of the students need more time conducting the laboratory and an extra session explaining how to use this technology.

However, all these difficulties were adequately addressed for the implementation of the second laboratory. Eighty percent of the students (21) reported that the time available was enough to perform the different activities. Moreover, the instruction provided was more precise than in the first laboratory. Not to mention that students' suggestions are focused on having more equipment and providing a real-time simulation. This latter is not the scope of this study, but it will be part of future work.

5 CONCLUSION

Many different technologies can be used to develop virtual learning spaces. One such option is using computational fluid dynamic packages and mixed reality tools. As a result, a standard procedure for designing such spaces was discussed. Data migration was guaranteed through software such as blender, where all file formats from the modeling and simulation stage were converted into a single structure to be exported into Unity. Despite Unity being equipped with several tools, it is necessary for the animation of the 3D modeling for some coding to be done in C# using Visual Studios. For the implementation of this laboratory, it was found that students are eager to work with this technology as long as a training session is provided before they are placed inside an MR environment.

Moreover, the time given to conduct the practices plays an important role. Students suggest that more time is needed to adapt themselves to this new technology. The CFD component enabled the students to comprehend how these hydraulic components function. According to student performance, they could characterize the hydraulic components using only the pressure and velocity field. However, physical interaction was still preferred over that of a virtual experience.

Future work will include making a robust model of these hydraulic components and simulating fluid dynamics in real-time from the HoloLens.

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A NEW SCHEMA OF LOGIC REPRESENTATION AND REASONING FOR AUTOMATED BUILDING CODE COMPLIANCE CHECKING

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ABSTRACT

Manual building code compliance checking is a time-consuming, laborintensive and error-prone process. Automated logic-based reasoning is an essential step in the automation of this process. There have been previous studies using logic programming languages for automated logic-based reasoning to support automated compliance checking (ACC) of building designs with building codes. As a high-performance implementation of the standard logic programming language, B-Prolog was widely used in these studies. However, due to the support of dynamic predicates and user-defined operators, the predicates' functions vary according to different user definitions; therefore, B-Prolog is sometimes not reliable for building code reasoning. As a more expressive, scalable, and reliable alterative to B-Prolog, Picat, a logic-based multi-paradigm programming language, provides a new and potentially more powerful platform for automated logic-based reasoning in ACC. To explore the potential value of Picat in ACC, in this study, the authors compared Picat and B-Prolog performance in automatically checking 20 requirement rules in the 2015 International Building Code. The experimental results showed that the automated checking for building codes in the B-Prolog version was faster than that in the Picat version, whereas the Picat version was more reliable than the B-Prolog version. This could be the result of B-Prolog using unification and Picat using pattern matching for indexing rules. More potential applications of Picat in ACC domain need further research. Furthermore, this schema could be used in the teaching of ACC to graduate construction students, illustrating the need to focus on the reliability, predictability and scalability of the process, in order to provide a practical solution to improving code compliance checking processes.

Keywords: Logic representation · Automated reasoning · Automated compliance checking · Building code · Artificial intelligence · Intelligent systems.

1 INTRODUCTION

Building design and construction activities must meet applicable requirements in building codes to assure the safety and well-being of construction workers and end users (e.g., occupants). Building code compliance checking in the past has relied heavily on manual efforts and the experience, skills, and judgment of building professionals, which is a time-consuming, labor-intensive and error-prone process [1]. The ongoing development of computing technology, especially the emergence of Building Information Modeling (BIM), provides a great opportunity to the automation of building code compliance checking, which is expected to improve the efficiency and accuracy of such checking. As a digital representation of the entire life cycle of a building, BIM not only provides a platform for timely information sharing for all parties involved in the construction process (such as builders, designers, and owners), but also enables the transformation of physical characteristics of buildings into computer-interpretable digital representations. This provides a solid basis for automated building code compliance checking. By converting building models into an international standard format, i.e., Industry Foundation Classes (IFC), and expressing building code requirements as compliance checking rules that can be executed by a computer, the rules can be used to automatically check building design information in the IFC-based BIM, enabling automated compliance checking of building designs.

Logic representation and automated reasoning is an essential step in automated compliance checking of building designs with building codes. Because the binary nature (True/False) of the smallest reasoning unit of first-order logic (FOL) naturally fits the representation of expected result (compliance/noncompliance) of automated compliance checking, and FOL enables fully automated reasoning, it is therefore commonly used in the logic representation and automatic reasoning of building codes [2,3]. B-Prolog, a logic programming language developed based on FOL, was adopted by previous studies due to its high performance [1,4,5]. However, due to the support of dynamic predicates and user-defined operators, the predicates' functions in B-Prolog vary according to different user definitions, which makes the code requirement reasoning unreliable sometimes. Also, the cessation of active development of B-Prolog limits its future applications in the ACC field. At the same time, Picat, a multi-paradigm programming language developed based on and served as a successor of B-Prolog, is the logical replacement and upgrade for B-Prolog. Compared to B-Prolog, Picat is more expressive, scalable, and reliable because it incorporates many features of both declarative language and imperative language [6]. These advantages of Picat provide a solid basis for its potential application in the ACC, so there is a need to explore the application of Picat in the ACC domain.

Based on the previous ACC research findings leveraging B-Prolog, in this study, the authors propose a new logic-based Information Representation and Reasoning (InfoRR) schema tailored to Picat. The proposed schema was used to implement logic representation and automated reasoning for checking 20 building requirement rules in the 2015 International Building Code [7]. The running times of the B-Prolog and Picat versions of implementing the proposed schema were compared and analyzed. The research presented in this paper provides (1) a foundation for future research on the logic representation and automated reasoning of building codes in the ACC field using advanced logic programming platforms such as Picat, and (2) a schema that can be used to teach graduate level construction courses in automated code checking, considering the practical needs of municipalities in terms of reliability of the results, aligned with the scalability and predictability of ACC processes.

2 BACKGROUND

2.1 AUTOMATED COMPLIANCE CHECKING

Automated compliance checking uses computing technology to check the compliance of building designs with applicable building codes in a way that is more accurate, efficient and economical compared to manual checking. Automated compliance checking is mainly built upon three parts: the digital representation of building designs, the computer-interpretable representation of building code requirements, and the automated compliance reasoning mechanism. Previous studies have investigated these three aspects extensively [4,8,9]. The following paragraphs mainly introduce the research work related to the computer-interpretable representation of building regulations.

Beach et al. and Rosenman & Gero proposed rule-based modeling methods to represent building codes [10,11]. Malsane et al. and İlal & Günaydın used object-oriented modeling to represent building codes [9,12]. In addition, some modeling methods based on the combination of ontology and natural language processing (NLP) have recently been proposed to achieve automated or semi-automated information extraction of building regulations [4,13].

Automated compliance checking systems were created and developed in different countries to enable efficient management of building construction projects, such as CORENET funded by Singapore's Ministry of National Development [14], Statsbygg Solibri system developed by Standards Norway and Norwegian BuildingSMART [15], SMARTcodes driven by the International Code Council (ICC) [16], and DesignCheck [15].

Although different systems and methods have been proposed in the past to pursue automated compliance checking, there are several limitations in the existing work: first, the existing logic-based representation methods are overly sensitive to the expressions of different types of information in building regulations, such as element definitions and quantitative requirements for a building element. Second, with the revision and update of building regulations, the update of the electronic representation and corresponding checking logics imposed high requirements on the computing skills of users. Third, building codes vary greatly among different countries and regions, so high demands are placed on the scalability and comprehensiveness of the logic representation method of an ACC system that tries to be widely applicable. Fourth, the existing automated compliance checking systems need some manual effort and support, and have not achieved full automation. In this paper, the authors aim to help address the first limitation.

2.2 LOGIC PROGRAMMING LANGUAGE

Logic programming languages use logic facts to represent facts that already exist and define logic rules to conduct inferences based on the logic facts. As a declarative language, it can be used to represent knowledge and allows machines to automatically make inferences, so it is widely used in the field of artificial intelligence. Common logic programming languages include Prolog, Answer Set Programming (ASP) and Datalog. Among them, Prolog is the most commonly used logic programming language. B-Prolog, as a high-performance implementation of Prolog, provides an efficient and versatile logic programming system. It has been used to support different tasks in the building construction domain such as building code compliance checking [5] and modular construction analysis with robotics automation [17,18]. There are three types of logic statements in B-Prolog: facts, rules, and directives. Logic facts are defined in the form of "p(arg1,arg2,...,argn).", where p is the name of the predicate, and arg1,arg2,...,argn are the arguments of the predicate. After the logic facts are defined, they become the basis of machine reasoning in the logic programs. Logic rules are defined in the form of "H:-B1,B2,...,Bn.", where H is the head of the rule, B1, B2,...,Bn represent the body of the rule, and :- is the operator for implication (i.e., it separates the head from the body of a rule). The head of a rule is considered to be true when its body part is evaluated to true. Logic rules define the rules for machine reasoning, and can also be used as the constraint of reasoning. Therefore, B-Prolog is very suitable for solving constrained optimization problems. Directives are defined in the form of ":- B1,B2,...,Bn.", which are mainly used to query the pragmatic information of the logic facts through the inference process [19]. Built upon B-Prolog, Picat was created and developed with logic programming concepts at the core. Picat builds a bridge between declarative language and imperative language because it incorporates many features of a declarative language, such as explicit unification, list comprehensions, constraints, as well as many features from an imperative language, such as assignments and loops [6]. This makes Picat a simple and powerful language for various applications. Table 1 comparatively illustrates the syntaxes of B-Prolog and Picat used in this study.

Table 1. Syntaxes of B-Prolog and Picat

Meaning	B-Prolog	Picat
Conjunction	,	, or &&
Disjunction	;	; or ||
Negation	not or \+	not or \+
Implication	:-	=>
Predicate	predname(arg1,arg2,…,argn).	predname(arg1,arg2,…,argn).
Rule	predh(arg1,arg2,…,argn):- pred1(arg1,arg2,…,argn), pred2(arg1,arg2,…,argn),…, predm(arg1,arg2,…,argn).	Head,Cond=>Body. (Each takes the form pred-name(arg1,arg2,…,argn))
Function	fun(arg1,arg2,…, argn).	fun(arg1,arg2,…,argn) = re-

If-then	Cond -> Goal; Goalelse.	if Cond1 then
		Goal1
		elseif Cond2 then
		Goal2
		⋮
		elseif Condn then
		Goaln
		else
		Goalelse
		end.

Table 1. Syntaxes of B-Prolog and Picat

3 PROPOSED INFORMATION REPRESENTATION AND REASONING (INFORR) SCHEMA

Based on existing logic-based information representation and reasoning schemas proposed in previous research [4,5], in this study, the authors proposed a new information representation and reasoning (InfoRR) schema to leverage the most recent advancement in logic programming for automated building code compliance checking. Compared to the previous schemas in literature, the proposed new schema divided the information representation into two parts: (1) the fundamental information elements, and (2) requirements, which were represented and stored in the form of logic facts and logic rules respectively. Fundamental information elements in this schema included instances that describe design information and building code concepts, and both were represented and stored in form of logic facts. The separate storage of logic facts and logic rules in the new schema facilitates information searching, reasoning, and compatibility with different logic programming implementations. Because both building code concepts and design information instances are represented in the form of logic facts, machines (i.e., logic reasoners) can automatically match and reason between the two under suitably defined logic rules, thereby outputting whether an instance of design information meets corresponding requirements of building regulations. In addition, the proposed new schema added secondary functions to obtain the running time of the codes, facilitating the comparison of different implementations. The structure of the proposed InfoRR schema is shown in Figure 1. Figure 2 shows the compliance checking process of building design information (e.g., Instance 1) to regulatory information (e.g., Logic Rule 1) under the proposed InfoRR schema. In this process, activation of logic rules is achieved through functional calls. Once a logic rule is activated, the applicability of the instance is checked by unification or pattern matching mechanism.

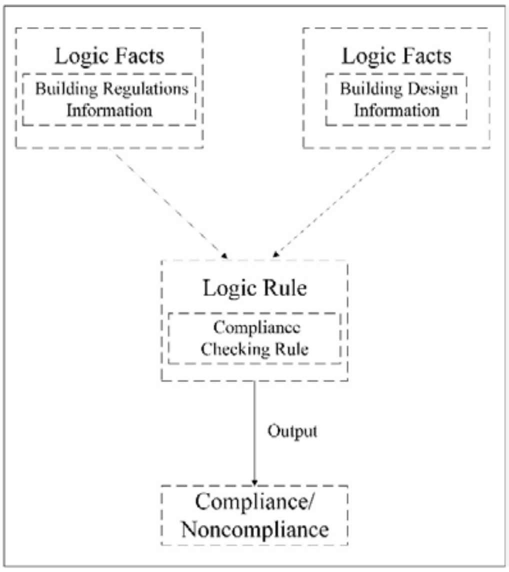

Figure 1. The proposed InfoRR schema

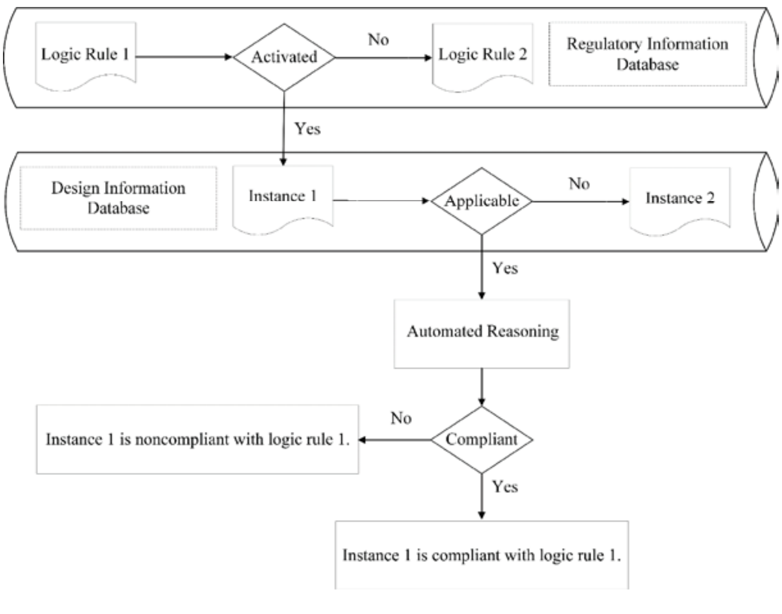

Figure 2. The compliance checking process of the proposed InfoRR schema

4 EXPERIMENT

The authors selected 20 building code requirements from Chapter 9 ("Fire Protection System") of the 2015 International Building Code [7] as the experimental basis. These requirements are mainly concerning the dimensions or quantities of fire protection equipment or related building elements. For each building requirement, the authors expressed the fundamental information elements with logic facts, wrote a corresponding compliance checking rule, and designed multiple building design instances that either comply with or violate the rule. Based on the logical analysis of the requirements, some rules may have more than one way of being violated, in which case multiple noncompliant instances would be created. The logic statements were implemented in both B- Prolog and Picat. It should be noted that logic-based reasoning can be implemented based on two assumptions: the open-world assumption and the closed-world assumption. In the open-world assumption, true information is explicitly represented, and any information that is not known to be true is treated as unknown. In contrast, in the closed- world assumption, any information that is not known to be true is treated as false. According to previous research [5], logic-based reasoning based on the closed-world assumption is more suitable for automated compliance checking applications, because it can achieve higher recall in noncompliance detection compared to that based on the open-world assumption, which means that the probability of missing non-compliant instances will be lower. Therefore, the experiments in this study were based on the closed-world assumption.

Secondary functions were defined and used during the implementations to provide functional support. For example, the built-in time counting function was used to record the running time of the program, and other functions were defined to implement unit conversions and quantity comparisons, etc. In addition, a loop function was defined in the main program to run the program ten times and record the running time of each time, to reduce the influence of random errors on the time measurement results. The two versions of the program were written and run in the respective executable files of B-Prolog and Picat, respectively, and output the checking results of 47 instances. The distribution of 47 instances was summarized in Table 2. For example, the 2015 International Building Code requires that the minimum dimension of exterior wall openings should be no less than 30 inches (762cm) (Chapter 9 Provision [F] 903.2.11.1.1) [7]. In this study, an exterior wall opening with a dimension greater than 30 inches and an exterior wall opening with a dimension less than 30 inches were designed to comply with and violate this rule, respectively, to test the effectiveness of the corresponding compliance checking rule. Five of the selected requirements have two possible violation scenarios of the rule, so the authors designed 2 noncompliant instances for each of these requirements. Chapter 9 Provision [F] 904.12.1 of the 2015 International Building Code (i.e., "The manual actuation device shall be installed not more than 48 inches (1200 mm) or less than 42 inches (1067 mm) above the floor and shall clearly identify the hazard protected.") [7] is an example of such requirement. Similarly, there is one requirement that has 3 noncompliant instances as shown in Table 2 below.

Table 2. A summary of the distribution of 47 instances

Number of requirements	Number of compliant instances	Number of noncompliant instances	Total
14	1	1	28
5	1	2	15
1	1	3	4

Table 2. A summary of the distribution of 47 instances

5 RESULTS AND DISCUSSIONS

The proposed InfoRR schema was successfully implemented in B-Prolog and Picat, and output compliance results for all instances correctly. In other words, both B-Prolog and Picat versions achieved 100% accuracy. Figures 3 through 6 show the screenshots of part of code implementations and corresponding checking results of design instances corresponding to the same rule in B-Prolog and Picat. However, there was a significant difference in their running times. It is evident from Figure 7 that the running time of the B-Prolog version was about half of that of the Picat version. According to Zhou et al. [6], the Picat version is supposed to be at least as fast as the B-Prolog version because "the Picat compiler translates loops and list comprehensions into tail recursion, which is further converted into iteration by tail-recursion optimization." A tail recursion is a special form of recursion where the function calls itself at the end of the function. The Picat compiler can avoid allocating a new stack frame for a function through tailrecursion optimization, thus consuming less memory space. The results in this study seem contradictory to Zhou et al. [6]. However, the conclusion of Zhou et al. took the implementation of Picat and B-Prolog on matrix multiplication as an example, and did not involve the field of ACC [6]. At the same time, tail recursion was not used in the code implementations in this study, which could be one of the reasons why the Picat version was slower than the B-Prolog version. On the other hand, B-Prolog adopted unification to select the applicable logic rule for a call, whereas Picat used patternmatching to execute logic rules. Pattern matching-based logic rules were fully indexed in Picat, whereas B-Prolog clauses usually indexed only one argument [6]. This difference could be another reason why the Picat version was slower than the B-Prolog version. However, the fully indexed feature gave Picat more scalability, which is reflected in the fact that the order of the logic clause elements that represent building code requirements did not affect the execution of the compliance checking in Picat. In B-Prolog, however, changing the order of (building code) regulatory information elements in a compliance checking rule could cause the rule to fail (to check). Figures 8 through 11 showed a comparison of the codes and outputs after changing the order of the regulatory information elements in the checking rule in B-Prolog. After the order of some logic clause elements was changed (e.g., "greater_than (Covered_kiosks_displays_booths_concession_stands_or_equipment,quantity12)" was changed to be the first element in this case), the program outputted an empty result, without explicitly indicating whether the instances comply with or violate this regulatory requirement (see Figure 11). In contrast, the change of order of the logic clause elements had no effect on the functionality of checking rules in Picat and the program could still output compliance results of instances after the changes, which showed that Picat version was more reliable and scalable.

```
expect_yes8:-
findall((Openings),(openings(Openings),have
(Openings,A_minimum_dimension),greater_than_or_eq
ual(A_minimum_dimension,quantity8),quantity
(A_minimum_dimension)),Xs)...
```

Figure 3. Part of code from the B-Prolog implementation of InfoRR

```
| ?- expect_yes8
openings8_1, is, compliant, with, section, 903, 2, 11, 1,
1, in, ibc, year2015
```

Figure 4. Sample output from the B-Prolog implementation of InfoRR

```
expect_yes8=>
findall((Openings),(openings(Openings),have
(Openings,A_minimum_dimension),greater_than_or_eq
ual(A_minimum_dimension,quantity8),quantity
(A_minimum_dimension))) = Xs...
```

Figure 5. Part of code from the Picat implementation of InfoRR

```
Picat> expect_yes8
openings8_1, is, compliant, with, section, 903, 2, 11, 1,
1, in, ibc, year2015
```

Figure 6. Sample output from the Picat implementation of InfoRR

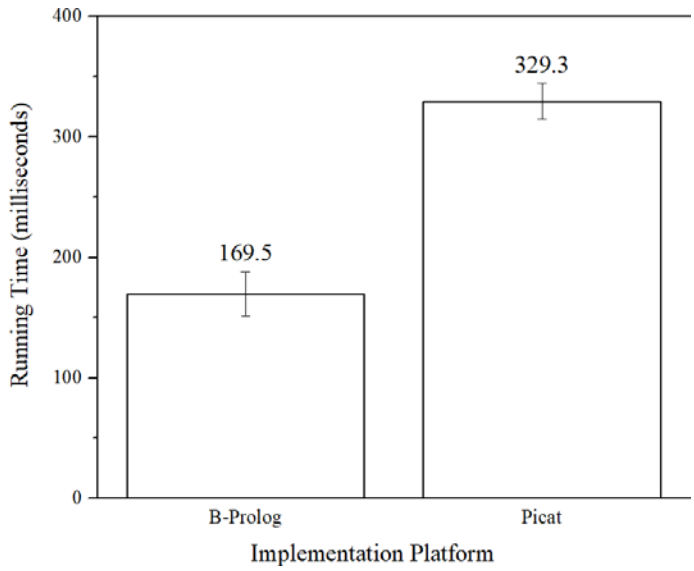

Figure 7. The runtime of the B-Prolog and Picat versions of the experiment

```
expect_yes12:-
findall((Automatic_sprinklers),
(automatic_sprinklers
(Automatic_sprinklers),installed
(Automatic_sprinklers),in_or_under
(Automatic_sprinklers,Covered_kiosks_displays_boo
ths_concession_stands_or_equipment),greater_than
(Covered_kiosks_displays_booths_concession_stands
_or_equipment,quantity12),in_width
(in_width)),Xs)...
```

Figure 8. Part of the code in B-Prolog

```
| ?- expect_yes12
automatic_sprinklers12_1, is, compliant, with, sectio
n, 903, 3, 3, in, ibc, year2015
```

Figure 9. Sample output from the B-Prolog code in normal order

```
expect_yes12:-
findall((Automatic_sprinklers),(greater_than
(Covered_kiosks_displays_booths_concession_stands
_or_equipment,quantity12),in_or_under
(Automatic_sprinklers,Covered_kiosks_displays_boo
ths_concession_stands_or_equipment),automatic_spr
inklers(Automatic_sprinklers),installed
(Automatic_sprinklers),in_width(in_width)),Xs)...
```

Figure 10. Part of the code in B-Prolog after changing the order of the regulatory information elements

```
| ?- expect_yes12

yes
```

Figure 11. Sample output from the B-Prolog code after changing the order

6 CONTRIBUTIONS TO THE BODY OF KNOWLEDGE

This study contributes to the body of knowledge in three main ways. First, a new information representation and reasoning schema was proposed to harness the power of recent advancement in logic programming while facilitating the comparison of different implementation methods. Two logic programming languages (i.e., B-Prolog and Picat) were used for ACC implementation under this schema, which showed that the proposed schema was robust and scalable. Second, this study demonstrated that Picat was a more feasible implementation method for information representation and automated reasoning of ACC. Although Picat-based implementation ran slower than B-Prolog-based implementation currently, the former was less sensitive to the expression of different types of regulatory information, and thus more reliable in the application of ACC. Last but not least, this research revealed the implications of the different mechanisms behind the different experimental results of the two implementations, and laid a solid foundation for future work on logic programming-based information representation and reasoning for ACC and for automation tasks in the architecture, engineering, and construction domain in general.

7 IMPLICATIONS FOR TEACHING

Although much research has been published on ACC processes such as [16,17], with ongoing effort towards its improvement, little has been discussed about how to teach students about this process. In general, due to the complex nature and interdisciplinarity of this process, graduate students in advanced courses may be more exposed to this topic. To this end, our experiment and our findings can be used as a basis for graduate construction students researching ACC. Our motivation is to improve the ACC processes using a practice-based approach. Therefore, by considering issues of reliability of the results, along with the scalability and predictability of the process and comparing different programming languages available, our experiment can be used as a case study to discuss user-centered research and automation in construction.

8 LIMITATIONS AND FUTURE WORK

The authors acknowledge the following limitations of this work. First, logic representation of regulatory information was implemented manually in this study. This process varies as individuals may understand and express the same building code requirement differently. Advanced artificial intelligence technologies, such as Natural Language Processing (NLP), could be helpful for the automation of this encoding process and reduction of the influence of individual differences and subjectivity. Second, the proposed InfoRR schema was only tested on dimensional and quantitative requirements in Chapter 9 of the 2015 International Building Code [7], and did not cover the other requirements of this building code. In order to represent and reason about other types of regulatory information, such as exceptions to a certain requirement and associations between different requirements, more modules need to be developed and embedded in the schema. Due to the complexity of logic relationship in building codes, the combination of multiple paradigm languages may need to be considered in the future. Third, the scalability and reliability of Picat were demonstrated through experiments in this paper, but the Picat-based implementation was not yet optimized with regard to its running speed. Full applications of Picat with optimized performance in ACC need to be further investigated in future research.

9 CONCLUSIONS

The logic representation and automated reasoning of building codes and regulations are an important process in automated compliance checking. Based on previous work on B-Prolog, this study proposed an InfoRR schema applicable to Picat, and successfully applied the schema to the logic representation and automated reasoning of 20 building requirement rules in the 2015 International Building Code [7] and 47 building design instances. The proposed schema could accurately output compliance results for all design instances checked. Compared to the B-Prolog version, the Picat version took longer to run, but was less sensitive to the order of regulatory information elements in the compliance checking rules, meaning that Picat was more scalable and reliable in supporting ACC. One reason behind the test results could be that B-Prolog uses unification to select an applicable rule for a call, which usually only indexes one argument, whereas Picat uses pattern matching to call the logic rules, which fully indexed all rules. The result in this study provides preliminary conclusions for the potential application of Picat in ACC compared to B-Prolog. More applications and tests of Picat in ACC need to be explored in future research.

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IMPROVING QUALITY INSPECTION AND PINION GEAR MANUFACTURING PROCESSES USING MACHINE LEARNING

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ABSTRACT

This work in progress study focuses on the implementation of machine learning methodologies into the pinion gear manufacturing processes at Stellantis to help address the issue of human subjectivity in quality classification. In this research, multiple machine algorithms are being examined including Logistic Regression, Naïve Bayes, Random Forest, and K- means to analyze pinion gear data, provided by Stellantis. The gear chart includes several variables out of which relevant gear attributes like pitch are being extracted. The extracted variables are then used for developing predictive machine learning models for pattern recognition of good and bad quality gears. To train the machine learning model, manually labelled gear charts are used with classification 0 (bad) or 1 (good), enabling the algorithm to learn to classify future data. The preliminary results on a small data sample show that the machine learning models have a decent prediction accuracy with the highest being Random Forest (72%) and the lowest being Logistic Regression (56%). The findings from this research show promise that machine learning algorithms can accurately classify gear data sets as good or bad quality in an efficient and consistent manner and thus reduce the delay and financial loss due to defect identification in downstream supply chain processes. We also plan to study the classified data (good and bad quality gears) using clustering approaches to determine any failure patterns or trends which can help in conducting root cause analysis.

Keywords: Subjectivity, Machine Learning, Supply Chain.

1 SECTION ONE

1.1 INTRODUCTION

Stellantis, formerly known as Fiat Chrysler Automobiles (FCA), is seeking to improve their pinion gear manufacturing processes by reducing the human error or variability factor during gear classification process of identifying acceptableor non-acceptable products from a quality standpoint. The current process involves subjectivity in form of the human judgement/testing of defects or potential defects in each pinion gear which leads to variability and inconsistency in the way good quality gears are identified. This research is focusing on improving the pinion gear manufacturing processes for the 9-speed front wheel drive (FWD), 6-speed rear wheel drive (RWD) and the 8-speed (RWD) transmissions. The existing process described in the previous section creates a substantial amount of subjectivity, resulting in inefficiencies in the supply chain. This research addresses two common yet significant manufacturing problems. The first is the substantial amount of subjectivity during component classification and quality defects. The second is the supply chain inefficiencies that result from classification subjectivity. The overall manufacturing process of the gear is presented in a schematic diagram in Figure 1 and described as follows.

The manufacturing processes for each pinion gear are identical, except for minor physical attribute changes dependent on the transmission application, like quantity of teeth, diameter, and pitch. Each pinion gear is first casted using an aluminum alloy material. Gear castings then proceed to a hob process to cut teeth into the gear surface. Following the hob process, gears are sent for heat treatment. Each gear is processed through tooth grinding equipment to eliminate any imperfections created by the tooling/moldings, such as large burrs that would result in excessive noise or component wear. After grinding, the inner diameter is bored to specification and the gear faces are ground.

Each gear must be tested for quality prior to assembly. These tests are conducted by analyzing physical traits or specifications via visual inspection and digital machine analysis. Visual inspection of the pinion gears is conducted after the hob process and during final packing. This process will allow different operators to inspect gears for different imperfections/defects. The digital machine analysis process provides a physical gear trace printout for each operator to analyze. Following the digital analysis and if the gear met specifications, each unit is then installed into the transmission housing and is prepared for final Noise, Vibration and Harshness (NVH) testing. Gears that do not meet specification are removed from the manufacturing process as scrap. During the inspection process, there is considerable variation in how different operators judge the gear quality. This can lead to either defective gears passing the quality check or acceptable quality gears being rejected, both situations lead to financial losses and possible delays in manufacturing process. To assess the impact of defective gears and identify underlying causes, Failure Mode Effects Analysis (FMEA) was conducted as presented in Figure 2. The current research project tries to address this issue of variation in quality assessment of gears by using machine learning.

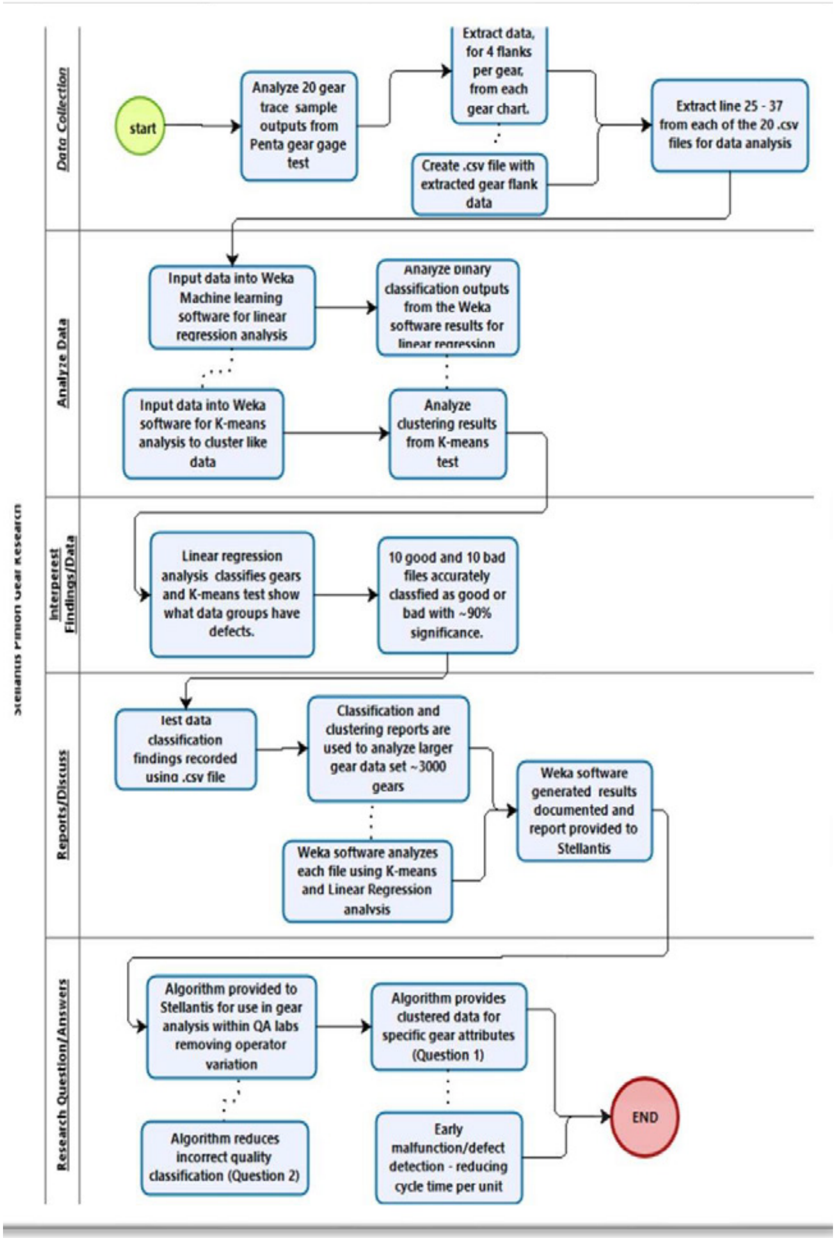

Figure 1 Stellantis pinion gear machine learning analysis

Process Step/Input	Potential Failure Mode	Potential Failure Effects	SEVERITY (1 - 10)	Potential Causes	OCCURRENCE (1 - 10)	Current Controls	DETECTION (1 - 10)	RPN	Action Recommended
What is the process step or feature under investigation?	In what ways could the step or feature go wrong?	What is the impact on the customer if this failure is not prevented or corrected?		What causes the step or feature to go wrong? (how could it occur?)		What controls exist that either prevent or detect the failure?			What are the recommended actions for reducing the occurrence of the cause or improving detection?
Hob/Grinding process - Visual Inspection	Teeth damage - surface damage	Additional processing wasted - next steps	5	Teeth damage - surface damage	7	Operator inspection/Judgement	2	70	Machine Learning Implementation
Quality Lab - Machine Analysis	Undetected damage - vital measurements.	Defective components released into final	7	Undetected damage - vital measurements.	5	Gear trace chart visualization from	5	175	Machine Learning Implementation
Packing/Assembly - Visual Inspection	Transmission is assembled with faulty gear - unuseable	Late shipment, part defect(s), extra processing (waste)	10	Transmission is assembled with faulty gear	7	Operator inspection/Judgement	7	490	Machine Learning Implementation

Figure 2 Pinion gear - FMEA

2 SECTION TWO

2.1 RELATED WORK

This research has been developed after conducting a review of the literature related to machine learning in the automotive industry and other high conformance manufacturing and the research on data clustering. Peres et al. (2019) found that the most common and significant problem within a Multistage Manufacturing Process (MMP) is variation. A possible solution for this would be to implement Predictive Manufacturing Systems (PMS) in a Multistage Manufacturing Process. PMS utilizes smart sensors and smart machines to monitor variation within manufactured components (Peres, Barata, Leitao, Garcia, 2019). These smart sensors/smart networks collect data, based on feature extraction, for performance assessment like logistic regression.

Studies have been conducted to isolate non-conforming products by utilizing machine learning in the form of data clustering. Machine learning, within a manufacturing environment, is utilized in the development of an Intelligent Supervisory Control System or ISCS (Escobar, Morales-Menendez, 2018). An ISCS is designed to analyze manufactured components and compare attributes to sample data. The pattern recognition developed within this system allows for decreased subjectivity during the component classification process by continuously building a machine learning knowledge base.

Abbas (2008) discussed the types of machine learning algorithms like K-means used to cluster data into smaller and like groups. Data clusters are formed with data that is like a specific collection of data while being different from much of the entire data set. Abbas discussed the four most common algorithms used to group data into clusters: K-means algorithm, Hierarchical clustering algorithm, Self-Organization Map (SOM) algorithm and Expectation algorithm.

3 SECTION THREE

3.1 MATERIALS AND METHODS

The methodology in this stage of research is analyzing known good and bad gear data using machine learning models and to develop an understanding of the attributes that result in a “good” (passed) or a “bad” (failed) gear. A small gear chart data sample with 20 cases was used for preliminary machine learning analysis with manually labelled 10 good/passing and 10 bad/failing gears. This dataset was used to train the machine learning models using the Weka machine learning software and the trained models were tested on a randomly generated test dataset to classify data as good or bad category. Due to the small sample size, we used the 5-fold cross validation approach to assess the classification performance of various machine learning models tested in this study including Logistic Regression, Naïve Bayes, Support Vector Machine, Multilayer Perceptron, and Random Forest. From Weka, a report is generated outlining the binary classification of each gear as “1” (Good) or “0” (Bad). The test data allows the algorithm to analyze specific features and add that understanding to its knowledge base (Escobar, Morales-Menendez, 2018).

4 SECTION FOUR

4.1 PRELIMINARY RESULTS

The research focuses on the three inspection points within the manufacturing process. The three inspection points are as follows: Hob/Grinding process (visual inspection), Quality Lab (Machine Analysis) and Packing/Assembly (visual inspection). Based on the previously mentioned inspection points, an FMEA analysis was conducted to highlight the failures with the highest probability. The FMEA analysis, analyzes the following factors: potential failure modes, potential failure effects, potential causes, current controls and recommended actions. The hob process, the first inspection point, has a potential failure mode of gear tooth damage or surface damage. The potential failure effect in this inspection point was additional processing and the potential cause is defective castings. The current controls for this stage are operator visual inspections and classification.

As shown in the FMEA, the potential failure mode during the quality lab inspection is undetected damage which decreases the accuracy of the collected data. The potential failure effect, during the quality lab inspection, is defective components being released into further manufacturing steps or final assembly. The potential cause of this failure is defective gears being released from the hob process and the current controls are analyzing machine generated trace charts.

Lastly, the potential failure mode during the packing/assembly inspection, which is the last inspection point, is transmissions being assembled using defective pinion gears. The potential failure effect of the last inspection point is supply chain delays and waste. Supply chain delays like late shipments, bottlenecks within the manufacturing process, extra processing, and component scrap/waste. The potential cause identified in the FMEA is gears being incorrectly classified as passing during the first and second quality inspection point. The current controls, like the hob grinding process, is operator inspection and classification.

The three previously mentioned inspection steps have failure modes that effect the overall manufacturing process. The FMEA isolates the most probable potential failures and develop recommended actions for each failure. Supporting the purpose of this research, the recommended action for each potential failure is the implementation of machine learning methodologies.

The secondary findings from preliminary analyses show a promising initial response to the subjectivity problem. The prediction performance of various machine learning models for the 5-fold cross validation are shown in Table 1.

1. Recall	2. Precision	3. Model
4. 0.568	5. 0.567	6. Logistic Regression
7. 0.703	8. 0.709	9. Naïve Bayes
0. 0.676	1. 0.677	2. Support Vector Machine
3. 0.730	4. 0.743	5. Random Forest
6. 0.649	7. 0.650	8. Multilayer Perceptron

Table 1 – Machine Learning Algorithms and Results

5 SECTION FIVE

5.1 CONCLUSIONS AND FUTURE WORK

The purpose of the research is to develop a solution that will reduce the subjectivity in the product quality classification of the pinion gear focusing on the machine analysis process and root-cause isolation of specific faults. This research develops a data knowledge base and utilizes machine learning algorithms to classify pinion gears into good and bad quality as a binary classification problem. Several supervised machine learning classification algorithms such as Naïve Bayes, Logistic Regression, Random Forest, and others were evaluated to classify the gears into good quality or bad quality.

The initial findings indicate the performance of machine learning models in the manufacturing and analysis to be of decent accuracy. The classification performance is expected to improve with more training data as the initial analysis was conducted on a very small data sample. An extensive dataset of approximately 3000 gears is being sorted and analyzed, using known values from Stellantis, to determine final classification and use it for training the machine learning models and examining their performance. The expected result from future work is to reach high classification accuracy throughout the analysis of approximately 3000 gear samples. If high classification accuracy is sustained, it will allow for the grouping or clustering of commonalities within the data set and data clusters can be utilized in root cause analysis. We plan to use a data clustering algorithm like K-means to cluster good and bad for pattern recognition to isolate any commonalities within the data set and thus conduct root cause analysis of defects.

Successfully classifying data sets using machine learning and data clustering will have a significant positive impact on each manufacturing process. The result of this research would be less subjectivity and fewer defects within pinion gear manufacturing and efficient root cause isolation, decreasing line/labor downtime and supply chain bottlenecks. We plan to evaluate the impact of quick and accurate identification of quality issues is gears on the overall manufacturing process, by developing discrete event simulation models in Simio software to model various scenarios where machine learning based quality issue identification is enabled and compare that with the current scenario. The simulation models would help in estimating the positive impact in terms of reduced delays and costs in the overall production process and downstream stages of supply chain.

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CURRICULUM DESIGN: ENVISIONING A LEARNING AND WORKPLACE ALIGNMENT MODEL FOR POLYTECHNIC INSTITUTIONS

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ABSTRACT

Polytechnic Universities with their emphasis on job-readiness, focus on developing the necessary workplace skill sets, to quicken a healthcare student's time spent in the classroom so they can join the workforce faster. Given the current healthcare crisis, changes are happening at warp speed in healthcare delivery leading to a disconnect between current education system and the needed competencies in the workplace. To narrow the gap between healthcare education, and the demands of practice this presentation proposes a curriculum design incorporating a novel Learning and Workplace Alignment model for an entry-level Occupational Therapy Doctoral Program using the framework of a polytechnic university.

1 INTRODUCTION

The focus of this presentation is on the curriculum design of an entry-level Occupational Therapy Doctoral Program using the organizing framework of a polytechnic university. Polytechnic Universities with their focus on job-readiness quicken a student's time spent in the classroom so they can join the workforce faster. For the health professions this translates into accelerated programs imparting specific sets of field-focused skills while staying in tune with accreditation standards. However, given the current healthcare crisis and trends in globalization, technological advances, and interdisciplinary care, it is necessary for health care related doctoral programs to provide candidates with an eclectic, dynamic and responsive set of skills, not only in health care delivery, but also in research, innovation, advocacy, mentorship and leadership. Incorporating these changes within a Polytechnic University framework necessitates an innovative approach to curriculum design. The goal of this presentation is to describe the curriculum design of an entry-level Occupational Therapy Doctoral Program that utilizes a novel Learning and Workplace Alignment model to provide learners with the skill sets needed to tackle the complexity of healthcare issues and concerns in dynamic milieus. This abstract begins by describing entry-level occupational therapy and situating the curriculum design for this profession within the polytechnic framework. Followed by an overview of the organization of the curriculum. And, concludes with a conceptual framework of the Learning and Workplace Alignment model.

2 ENTRY-LEVEL OCCUPATIONAL THERAPY

The entry-level nature of the program means that the program prepares students to enter the workforce. Occupational therapy is an evidence-based health care profession deeply rooted in science that helps people across the lifespan adapt to injury, illness, or disability. Occupational therapy helps people function in all of their environments (e.g., home, work, school, and community) and addresses the physical, psychological, and cognitive aspects of their wellbeing through engagement in occupation (everyday activities). Thus, the program seeks to produce a graduate who has acquired the knowledge, skills and attitudes required for entry into the profession of occupational therapy (American Occupational Therapy Association, 2022).

3 CONCEPTUAL FRAMEWORK OF THE PROFESSION

The guiding components of the curriculum philosophy are the therapeutic application of occupation - the concept that humans are occupational beings, and the complex processes by which people find meaning and health through the interactive person-environment process of 'performing' or engaging in occupations. Embedded within the curricular framework is the singular principle that an individual's occupational performance can be positively shaped by focusing on the "whole person" and attending to his/her physical, psychological, spiritual, social and cultural concerns as influenced by both internal environment (within a person) and an external environment (outside a person). Having occupation and occupational performance as the underlying theme in the curriculum within a critical thinking/clinical reasoning environment that is self-directed and practice-driven fosters in students the capacity to examine and analyze the occupations people perform and enables them to use occupation as the medium to assist people to live their lives to the fullest extent possible (American Occupational Therapy Association, 2021).

4 PROGRAM ALIGNMENT WITH INSTITUTIONAL MISSION AND CORE INSTRUCTIONAL METHODS

The mission of the University states "Utah Tech University is an open, inclusive, comprehensive polytechnic university featuring active and applied learning to advance students' knowledge and skills while fostering competent, resilient, lifelong learners to succeed in their careers and personal lives as creators, innovators, and responsible citizens" (Trailblazing Distinction, 2020-2025 Strategic Plan, 2020).

As an example, occupational therapy curriculum was developed with the University's mission, mission-aligned core instructional methods (Active Learning, Applied Learning, Authentic Learning, Inclusive Pedagogy/Andragogy, and Student-centered) and Institutional Learning Outcomes (Skills, Knowledge, Innovation, Responsibility, and G.R.I.T. or growth mindset, relationship building, intentional learning, tenacity) as integral parts that are central to the educational process. The Profile of the occupational therapy graduate as envisioned by the program is depicted in Figure 1.

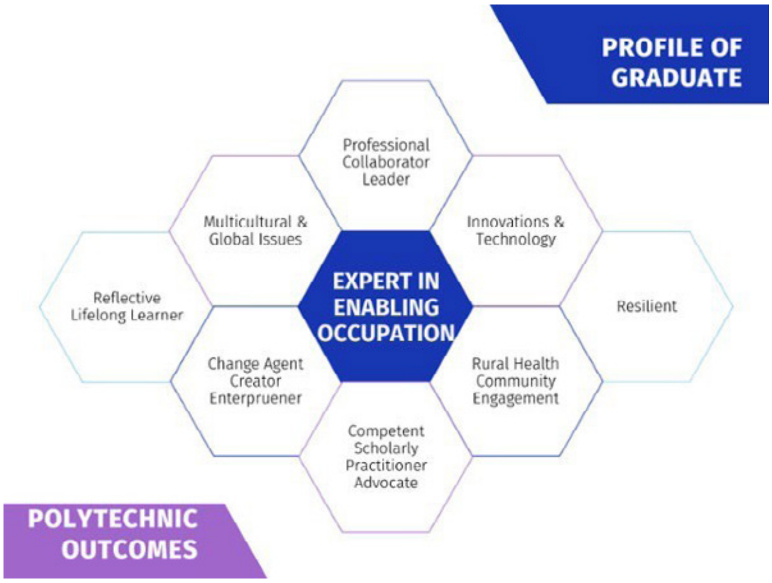

Figure 1. Profile of Occupational Therapy Graduate from a Polytechnic Institute

Rooted in the University's polytechnic culture, the program is designed to promote the development of occupational therapists that are able to flourish in dynamic work settings. The following outlines the program's alignment with the University's mission statement, mission-aligned core instructional methods, and institutional learning outcomes:

- Open Education: The program aligns with the University's strategic decision of open education, which is a particular way of providing education that uses digital technologies, removes barriers, and makes learning accessible, abundant, and customizable for all. Multimedia content (including reusable learning objects) and strategies for learner support through video-conferencing and web–based platforms that will be developed, and/or open source teaching materials that are modified and used by the program will be shared and made available on the University's Open Education Platform.
- Inclusive: Given that students come to the educational experience with different expectations and backgrounds, we will give special attention to providing equal access and opportunities to all and will be prepared to meet a variety of learning needs and preferences.
- Comprehensive Polytechnic: Characterized by active and applied learning, and career development through industry partnerships, our polytechnic program aspects are met through fieldwork (clinical rotations) and community-based experiences. These experiences in particular will provide the pathway for intentional learning through engagement, inter-professional interaction, and partnerships with workforce and community stakeholders. The Program's Learning and Workplace Alignment model is based on the belief that progressive real-world contexts best facilitate student learning. Learners practice increasingly complex skills in settings ranging from low-realism situations in classrooms and laboratories to high authenticity 'real-life' simulations of practice settings, to real-life contexts. Faculty members will adapt the complexity of the skill to be learned and/or alter the setting's congruence to real world practice to promote adaptive learning.

Overall, the curriculum is designed to reflect a balance and interweaving of content driven experiences (course-based) and process driven experiences (applying the occupational therapy process in any setting/population). This occupational therapy program is fundamentally compatible with the mission of the University.

5 METHOD OF DELIVERY

The Occupational Therapy Doctoral curriculum will be provided through a blended model of delivery. Web-based and face-to-face learning methods will be strategically used in a way that promotes higher order thinking skills such as critical thinking, problem solving, and collaboration. Competency in these skills is critical for today's health professional. In addition, it enables online access to professors, study materials, study groups, and submission of work.

6 ORGANIZATION OF CURRICULUM

The proposed curriculum's content is grounded in the history, theories, and science of occupation and, it is this crucial foundation content that is addressed in the initial phase of the curriculum sequence. Its early placement establishes students' perspectives as occupational therapists, and "occupation" as the encompassing context in which all other content is perceived and integrated. Occupation is reiterated, applied, and expanded within each later course, with increasing complexity and elaboration. The initial phase of the curriculum sequence also includes advanced studies of the science of the human body and the conditions that affect it.

Content related to applied science/conditions (e.g., mental and physical conditions) are integrated throughout the curriculum to provoke learning of client-specific occupational therapy issues. This organization requires that students relate information across areas of practice and diagnostic groups, and integrate learning from earlier courses into successively more complex treatment planning situations, ultimately preparing them to address the complex situations facing occupational therapists in practice and research.

During the final phases of the curriculum sequence, students complete two 12-week clinical fieldwork in practice settings, some of which may be rural areas, and an in-depth doctoral experiential component or Capstone. The Capstone Experience, requires the student to apply the knowledge and skills developed in courses and clinical fieldwork rotations to the design and implementation of an applied and innovative capstone project in response to an identified need in the field.

7 EDUCATIONAL CONCEPTUAL FRAMEWORK: LEARNING & WORKPLACE ALIGNMENT MODEL

In accord with the Polytech institution's motto, "Active Learning. Active Life" the Learning and Workplace Alignment Model is primarily based on Kolb's Experiential Learning

Theory (1984). As per Kolb, "Learning is the process whereby knowledge is created through the transformation of experience" (Kolb, 1984, p. 38). The experiential learning cycle is a four-step learning process that is reiterated in every interaction and experience. The four steps are Concrete Experience (new situation or similar situation under different circumstances) – Reflective Observation (think through and assimilate) – Abstract Conceptualization (think through and expand information base) – Active Experimentation (apply new information and observe resulting situation). This is a reoccurring process that is a powerful teaching mechanism for faculty and an intuitive self-assessment tool for the learner. A faculty member can select the most appropriate approach (es) and method (s) on the belief that increasing real world contexts best facilitate student learning and self-awareness of abilities. Wherever possible, faculty can use the coaching and facilitating approach to promote active student participation / behaviors in the learning process thereby creating successful learning experiences for the student. Faculty members adapt the complexity of the skill to be learned and/or alter the setting's complexity to real world settings to promote learning. In addition, by critically reflecting on their own experience, students change their patterns of thinking, feeling, believing, and doing - thereby being empowered and motivated to challenge the status-quo. By critically reflecting on self and sharing these reflections with their peers and others, students build the skills to question assumptions and to examine alternative ways of being and doing. This 'thinking about your own thinking' enables students to assess their own understanding and behavioral performance.

The concept that increasing complexity of real-world settings enhances learning was initially mentioned by John Dewey (1938) in his Experience and Education when he stated, "all genuine education comes about through experience" (p.13). Kolb (1984) and later Barnett (1989) expanded earlier work to develop a cyclic Model of Reflective Thought and Action that occurs when a concrete experience leads to reflective observation, abstract conceptualization, planning how to alter actions and, finally, active experimentation.

Mezirow (1978), the proponent of transformative learning believed reflection to be a critical component of the learning process. As per transformative learning theory the process of "perspective transformation" has three dimensions psychological (changes in understanding of the self), convictional (revision of belief systems), and behavioral (changes in lifestyle). From the perspective of the Learning and Workplace Alignment model, by undergoing critical reflection the student internally changes his or her ways of thinking, feeling, believing, and doing.

The Dreyfus model of skill acquisition identifies novice to mastery levels of skill in categories of recollection, recognition, decision, and awareness (Dreyfus et al., 1980). Or the four stages of competence used in psychology to explain the development of clinical reasoning (unconscious incompetence, conscious incompetence, conscious competence, and unconscious competence) (Adams, 2015). The Learning and Workplace Alignment Model of the program scaffolds learning from simple with the novice learner to complex and multifaceted with the more advanced learner. The intent is to provide the "just right challenge" at each stage of learning as the student is transformed into the polytechnic graduate or entry-level professional.

The conceptual framework of education espoused by the Learning and Workplace Alignment model also embraces the principles of self-determined learning - heutagogy (Kenyon & Hase, 2001). In this learning approach in addition to thinking deeply about a problem and its solution, they also reflect on their problemsolving process by questioning their assumptions thereby gaining insight into what they are learning and how they learn. Students are encouraged to find problems to solve – to seek out areas of uncertainty and complexity. The learner evolves to analyst and synthesizer, developing a wide range of cognitive and metacognitive skills. Thereby being highly autonomous and self-determined, equipped with skills that prepares them to confront complexities in today's workplaces (Blaschke, 2012) including healthcare delivery. Embedded in this framework is the educational philosophy of lifelong learning that both faculty and students believe in and value. This approach aligns well with blended teaching and learning and has been used to guide how distance education is developed and delivered (Blaschke, 2012).

The novel Learning and Workplace Alignment model approach to education stems directly from the University's polytechnic mission to educate highly skilled, career-ready, innovative, and life-long learners. Employers, particularly in the healthcare industry, look for innovativeness, creativity, self-directedness, and whether employees understand how they learn. These are all foundations of the Learning and Workplace alignment approach. We believe the preparation of healthcare professionals at the doctoral level is optimized by using this approach.

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MOLECULAR TOOLS TO STUDY LYSINE DEACYLASES

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ABSTRACT

In natural sciences, the appropriate tools are often the key to success. In biochemical research molecular tools such as enzymatic assays and specific antibodies provide the capability to measure processes in the complex surroundings of a living cell or organism. In our lab we create new tools to study a class of enzymes that regulates a multitude of cellular processes by controlling the modification of lysine residues with acyl groups. In particular, we employ the incorporation of non-standard amino acids in proteins to monitor their interaction with other proteins, create new enzymatic assays and design engineered variants. These tools will be invaluable in characterizing the enzyme's enzymatic properties and to deduce their role in fundamental physiological processes such as immunity, glucose homeostasis and aging.

Keywords: ***Lysine Deacylases, Genetic Code Expansion, Post-translational Modification.***

1. INTRODUCTION

Lysine acylations are widespread post-translational modifications of proteins that occur in all kingdoms of life. The level of these modifications is dynamically controlled by a comparatively small number of lysine deacetylases (KDACs) [1].

KDACs play an important role in many physiological processes. Originally discovered on histones, they are known as repressors of transcription because removal of the acyl groups increases histone-DNA contacts, leading to chromatin compaction. The discovery of thousands of acylation sites in proteins of various organisms from all kingdoms of life illustrates the importance of this modification for the regulation of cellular processes.

Because of their role in numerous common diseases such as cancer, diabetes, neurodegeneration and aging KDACs are in the spotlight of pharmaceutical research [2]. Substances that specifically activate or inhibit individual KDACs are therefore urgently needed. This requires the availability of reliable assays suitable for high-throughput screening. Substrate selectivity is another critical parameter of KDAC action. How these enzymes are directed towards particular locations in the cell and how they recognize particular substrate proteins is actively investigated.

We use genetic code expansion to develop a highly sensitive KDAC assay [3] and create KDAC variants with altered substrate preferences by directed evolution in bacteria [4, 5]. We employ this KDAC assay to identify a new class of inhibitors with exquisite specificity for the SirT1 isoform of KDACs [6]. Moreover, we use genetically encoded UV-activatable crosslinker amino acids to study acylation-dependent interactions in living cells [7, 8]. Here we showcase examples from our recent work to illustrate how these tools help to address long-lasting questions in the field of KDAC research.

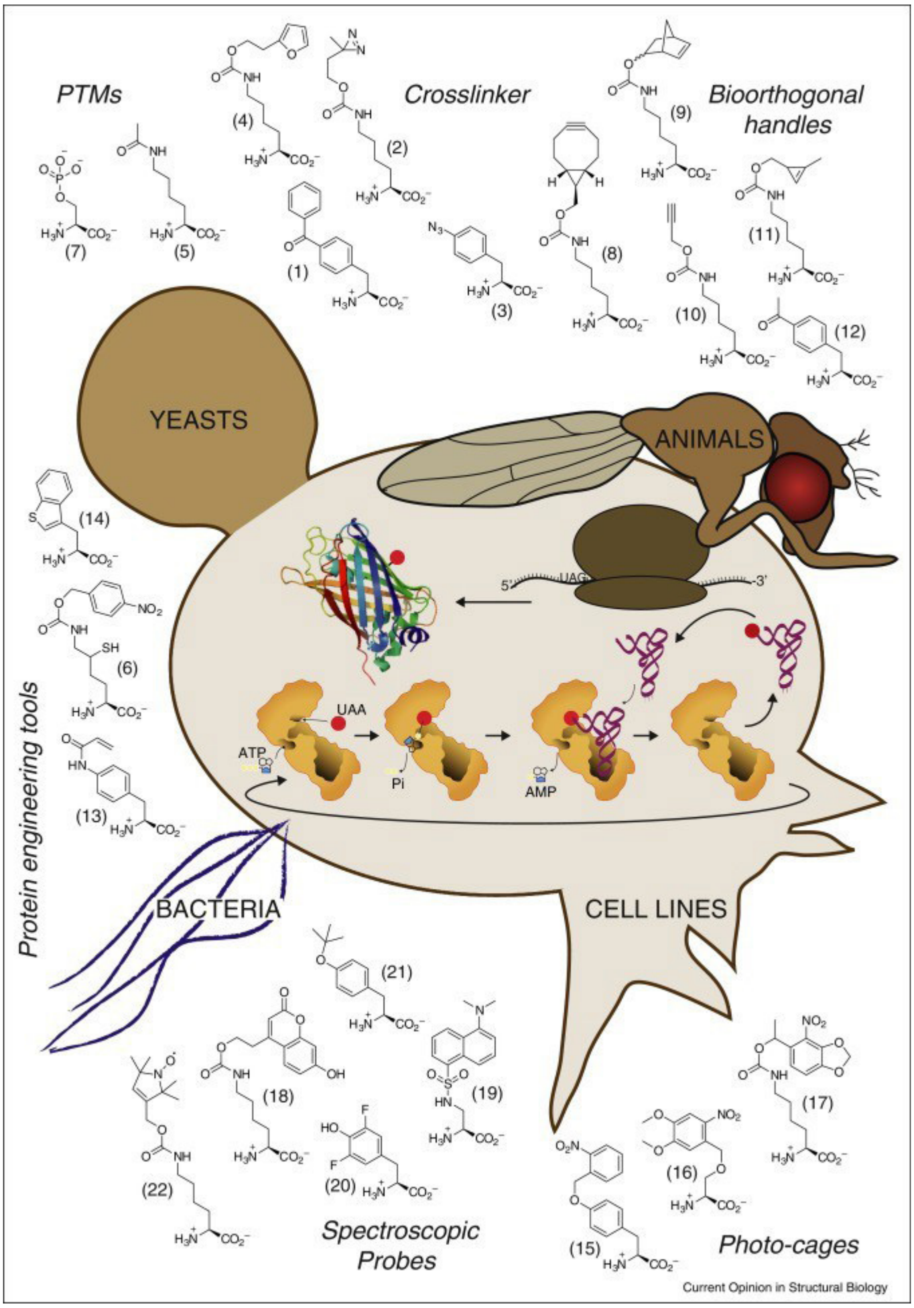

Figure 1: Genetic Code Expansion allows the incorporation of non-standard amino acids in proteins of various organisms. Reproduced with permission from Elsevier [9].

2. RESULTS

2.1 INCORPORATION OF NON-STANDARD AMINO ACIDS BY GENETIC CODE EXPANSION

The incorporation of non-standard amino acids in response to the amber stop codon (UAG) facilitates the biosynthesis of proteins with unique modifications (Fig. 1) [9]. To achieve this, an orthogonal aminoacyl-tRNA synthetase (aaRS)/tRNACUA pair is expressed in the host organism. The aaRS of this pair was engineered to load a non-standard amino acid onto its cognate tRNA, which in turn was engineered to direct the incorporation of this non-standard amino acid in response to amber codons. Using this approach, a variety of useful non-standard amino acids have been introduced into proteins of different organisms, from prokaryotes and yeasts to whole animals and plants.

2.2 A HIGHLY SENSITIVE KDAC ASSAY

Using the genetic incorporation of acetyllysine, we have developed a new KDAC assay based on the deacetylation of an essential lysine residue in the active site of Firefly luciferase [3]. We demonstrated that several KDACs can reverse this modification and thus activate luciferase. This new assay is extremely sensitive, reliable and fast (Fig. 2).

We have subsequently used this assay to screen a library of chemical compounds for inhibitors of the KDAC SirT1 [6]. This identified a new class of inhibitors with particularly high preference for this isoform. Hit optimization created a compound, which is almost as effective as selisistat, presently the gold standard of SirT1 inhibitors, and significantly superior in its ability to discriminate SirT1 against closely related isoforms.

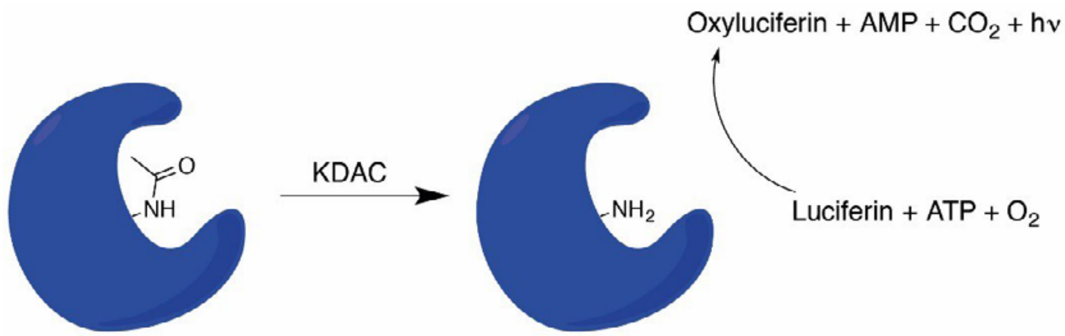

Figure 2: Acetylated Firefly luciferase is activated by KDACs.

2.3 A BACTERIAL SELECTION SYSTEM FOR THE DIRECTED EVOLUTION OF KDACS

Using a similar strategy, we have designed a bacterial selection system for the directed evolution of KDACs towards specific acyl substrates and bioorthogonal lysine modifications (Fig. 3) [4]. The new enzymes can be used to partially complement KDAC deletion strains to determine the physiological role of specific lysine acylations. Bioorthogonal “eraser” enzymes facilitate the activation of pro-peptides or pro-enzymes by removing protecting groups attached to lysine residues. These bioorthogonal “eraser” enzymes could therefore find application in prodrug strategies for cancer therapy.

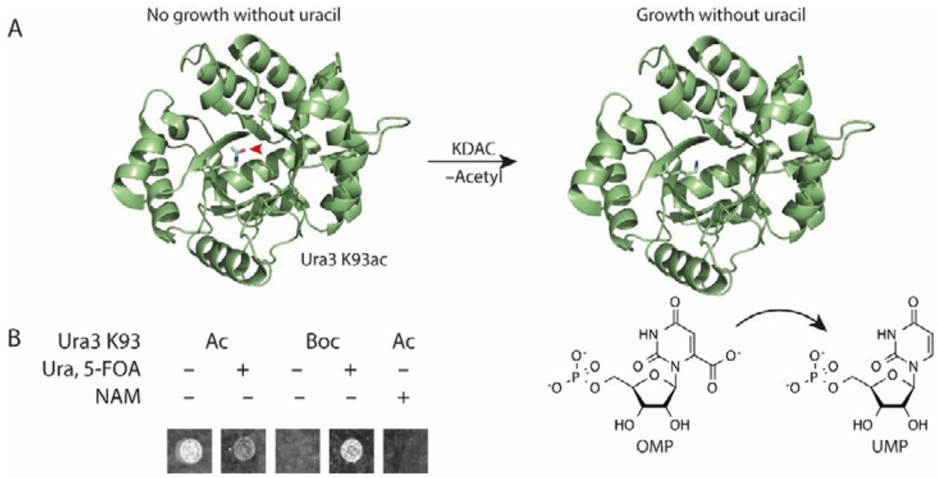

Figure 3: A Bacterial selection system for KDACs based on the acetylated reporter enzyme Ura3 K93ac.

2.4 DETECTION OF LYSINE ACETYLATION DEPENDENT PROTEIN-PROTEIN INTERACTIONS IN LIVING CELLS

Lysine acetylation is often employed by cells to control protein-protein or protein-DNA interactions. By genetically encoding photo-crosslinker amino acids we mapped the footprint of the catalytic subunit of the RSC chromatin remodeling complex, Sth1, on the nucleosome in living yeast [7]. Our in vivo data agree well with biochemical data and structural information available for this remodeler. By manipulating the acylation state of histones, we identified the bromodomain of Sth1 as a recognition module for H3 K14 acetylated nucleosomes (Fig. 4).

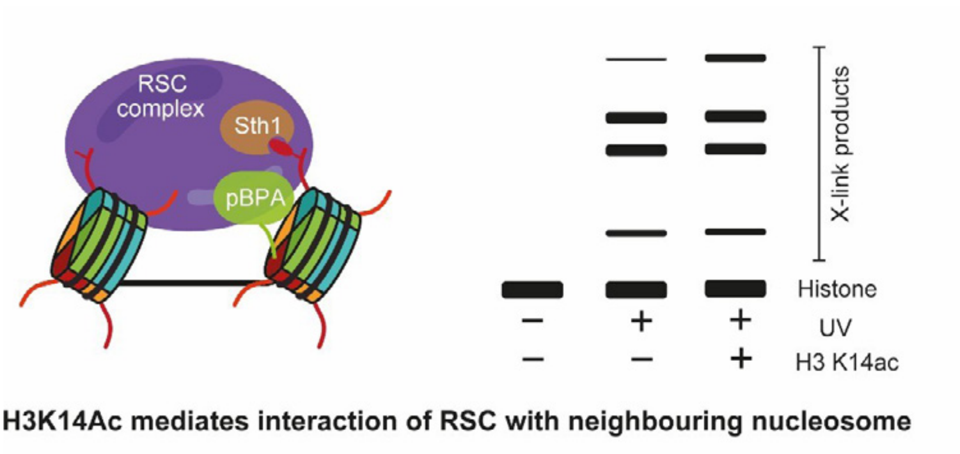

Figure 4: Incorporation of crosslinker amino acids in histones allows the detection of H3 K14ac dependent interaction of chromatin remodeler RSC with nucleosomes.

3 CONCLUSIONS

The creation of new molecular tools for KDACs with the help of genetic code expansion offers new opportunities to study this important class of enzymes. Our lab is actively developing further tools along these lines. The production of site-specifically acetylated substrate proteins will help to elucidate substrate-specific effects, for example, of post-translational modifications of KDACs. Such modified KDACs can also be produced for example by genetically encoding phosphorylated serine or threonine residues. Furthermore, using the directed evolution system for KDACs we have developed inhibitor-resistant mutants that can be used to study the side effects of the inhibitor or to block the activity of the endogenous enzyme in cells that expressed an inhibitorresistant variant with additional mutations.

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THE CHALLENGES OF OPERATING ELECTRIC AIRCRAFT FOR PASSENGERS SERVICE PROVIDERS

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ABSTRACT

The aviation industry is set to see another significant leap in new technology, namely electric aircraft. While electric aircraft manufacturers are hoping to incorporate electric aircraft into the national airspace system, emerging challenges are anticipated. This study explored existing research and literature by using VOSviewer to visualize research themes and interconnected clusters followed by interviewing practitioners to reflect on theoretical basis and collect the firsthand data. VOSviewer showed regulations (U.S.A. and Canada), engine design, continued airworthiness, and other concerns were primarily studied. Second level analysis helped discover aircraft specification, service and maintenance, and project management perspectives were critical. Voluntary aviation practitioners were recruited and interviewed who indicated that airports and airlines possessed different means of benchmarking success. MATLAB was used to develop a Risk Matrix for risk assessment when electric aircraft is operated.

Keywords: ***Electric aircraft, aviation batteries, EAS, SCASD, Risk Matrix***

1 INTRODUCTION

In recent years innovations in structure design, materials, payload, and battery technologies have allowed engineers to develop manned electric aircraft for passenger and cargo transportation. Besides the small-sized electric aircraft developed as prototypes, large manufacturers have been investing in high-payload zero-emission aircraft such as Airbus ZEROe [1]. Other sectors of air transportation including general aviation also saw the convenient mobility of using e-aircraft, for example the vertical takeoff and landing (VTOL) aircraft, for inner/inter transportation between urban cities and remote townships. In the wake of the new technology, the Federal Aviation Administration (FAA) had approved USD 100 Million into developing the next generation of sustainable aircraft [2]. This investment awarded to industry leaders like GE Aviation, Honeywell Aerospace, Boeing, and Pratt & Whitney to work on comprehensive and reliable systems that will support the operation of the future electric aircraft.

A study by Prapotnik Brdnik et. al. [3] confirmed that the most feasible electric aircraft to be electrified is the regional turboprop regarding investment, payload, distance, infrastructure and operational cost. Airports need to make substantial additions and upgrades to their infrastructure to enable fully electric or hybrid aircraft operations such as battery stations [4]. To test the theory, Salucci and research associates used an airport in Athens, Greece and discovered that even for the smaller regional jets, direct charging stations would not be suitable due to the size of the batteries.

The foundation of this study stemmed from the concerns of technical achievements, government's standards, preparedness of practitioners (airlines and airports), potential market and cost-benefit, just to name a few. Research areas are listed below:

1. The key innovative fields related to electric aircraft that had been investigated.
2. Existing governmental standards and supports for the R&D and operations of electric aircraft.
3. Needed infrastructures investment for airports or airlines to facilitate aircraft operations.
4. Governmental subsidies for air service providers when operating electric aircraft.
5. Operational risks and safety related to engineers, customers, and airline practitioners.

2 LITERATURE REVIEWS

2.1 THE BASICS OF ESSENTIAL AIR SERVICE (EAS)

In response to the Airline Deregulation Act (ADA), Congress added section 419 to the Federal Aviation Act where the Essential Air Service (EAS) program was put into place to guarantee that small cities maintain a “minimum level” of scheduled air service [5]. This legislation requires all candidate communities to see at least ten enplanements per day, excluding Alaska, Hawaii, or communities that sit 175 miles or more from the nearest medium or large hub airport or otherwise waived by the Secretary of Transportation.

In communities where EAS is utilized, the program brings to an area can boost economic growth [6]. As a business entity, profit is the lifeblood to remain perpetually sustainable. While some airports are served by turbo-propped 9-seat Cessna 402 or Tecnam P2012, some currently served with 50-seat aircraft such as Bombardier CRJ- 200 under EAS program such as Billings, Montana [7].

Kanafani and Abbas [8] looked at three California cities (Bakersfield, Redding, and Monterey) and how they were affected by the Airline Deregulation Act (ADA). Cities lacking air services would encounter slower economic growth than those with air services, such as City of Monterey, CA. An article written by Blonigen and Cristea [9] had discovered that a region’s additional income has been correlated to the increased amount of air service. In their study, when passenger traffic increased by 50%, it would lead to a 1.55% (conservatively) increase in population size as well as hundreds of millions of dollars of the local economic growth.

2.2 SMALL COMMUNITY AIR SERVICE DEVELOPMENT GRANT (SCASD)

A study by Wittman [10], explored other large type of grant besides EAS, namely Small Community Air Service Development (SCASD) grants. SCASD grants provide funding to airports to complete specific incentive packages to either attract new air services or promote existing services. SCASD grant is relatively small but flexible compared to EAS. Wittman proposed viewpoints for SCASD grants to become more successful. The first point was to attract new air services. If the airport could attract and maintain air service in the first 28 months after grant was awarded. it showed a higher likelihood of staying long term. The second point, related to marketing existing services, was that if the airport could improve its level of service by greater than 10% in 28 months, it was more likely to succeed with 73.1% of the 26 grants succeeding.

2.3 ELECTRICAL AIRCRAFT POLICIES AND CERTIFICATION

Federal Aviation Administration (FAA) type certification processes mandate safety and reliability measurement for future electric or hybrid-electric aircraft. As of a recent FAA ruling regarding magniX electric engines, electric propulsion systems as an aircraft design feature were still considered novel and unusual, requiring a more stringent certification process [11]. When the original 14 CFR Part 33, which covers airworthiness standards for aircraft engines, was developed, the FAA considered internal combustion systems and the potential hazards that they specifically may present. Obviously, since electric engines behave quite differently and possess unique sets of potential flaws related to mechanical, thermal, chemical, and high-voltage operating conditions, 14 CFR Part 33 or even Part 21.47 may contain inadequate certification standards against innovative engines and associated propellers. Therefore, the engine developing community has required the development of special conditions.

The FAA's response to electric engines was shown in the Notice of Proposed Rulemaking (NPRM) in 2020 [11] that proposed to collect public voice to help certify new aircraft with innovative or unusual propulsion engine systems. Comments were submitted by interested organizations and individuals, suggesting that this particular certification process should be more smooth as new electric propulsion technology emerged. On September 27, 2021, the FAA released the "Special Conditions: magniX USA, Inc., magni350 and magni650 Model Engines; Electric Engine Airworthiness Standards" via Federal Register to certify magni350 and magni650 electric engines [12] Federal guidelines have been set to streamline and speed up the process for electric propulsion aircraft to become feasible and commonplace.

2.4 INFRASTRUCTURAL CONSIDERATIONS

Electric propulsion systems. Electric propulsion systems for aircraft have been seriously investigated to fulfill emissions-reduction goals and green-energy policies such as pure-electric (PE) engines, which use a battery to store energy [13]. The introduction of aircraft types was expected to substantially affect part of airport facilities and call for a renovation or even a new infrastructural installation.

Recharging facilities. The facilities for battery recharging are crucial, categorized into two basic types: battery plug-in chargers (BPCs) or battery swapping stations (BSSs). Using a BPC is similar to current fuel-refilling systems like automotive counterparts. BPCs seem less complicated in operations than BSSs but have the major shortcoming of taking more time, especially sensitive to the size and weight increase. Trainelli et al. used an international airport as the case that incorporated considerable daily turboprop regional operations, discovered that both BPC and BSS systems alone would not be able to sufficiently provide power supply to the smaller regional planes.

Cost. Another challenge is the cost. Battery swapping stations would make it possible to take advantage of relatively reasonable and stable electricity prices by allowing for recharging at any time, regardless of the presence of an aircraft. However, battery procurement and inventory cost would be a financial burden [14].

2.5 EFFICIENCIES OF BATTERIES

Passenger air transportation has been expected to be gradually restored in the post-pandemic era [15]. However, increasing emission restrictions are being considered in key markets such as European nations. The Advisory Council for Aeronautical Research in Europe set to reduce emissions in air transport by 90% by 2050. Electrification of aircraft propulsion will become more necessary but is limited by battery capacity, which can provide only a fraction of the energy per kilowatt per hour per kilogram (kWh/kg) [3] Batteries currently have a specific energy of up to 0.25 kWh/kg, while that of kerosene is 4 kWh/kg when used in an internal combustion process. Significant improvements in light-weight high-capacity batteries for large aircraft remain challenging kilogram. Remarkably, Heart Aerospace's development of the ES-19 aircraft, which could seat up to 19 people, had proven that larger electric aircraft were possible [16] yielded two hundred preorders.

2.6 OPERATIONAL SAFETY AND RISK MANAGEMENT

Relationship between engineers and airline practitioners. Enhanced technologies, including developed software hardware and satellite communication, significantly reduce pilot workload in the aviation industry [17]. Previous studies also showed that human errors had been implanted in approximately 70% to 80% of all accidents over 20 years. Communication is critical for cockpit crewmembers to share a "mental model" or common understanding of the nature of events relevant to safety and the efficiency of the flight [18]. Communication between the engineering design and the airline practitioner is also essential. Engineers would need to design a product that meets the airlines' safety and economic requirements. In the same vein, airlines would need to provide proper training to qualify their pilots [19].

Relationship between airlines and customers. The growing importance of air travel has led to an increase in the number of airline companies, resulting in fierce competition in the industry [20]. To retain current customers while attracting new ones, airline companies offer many different services. Most airlines measure their services based on passengers' perception but lacking adequate knowledge of passengers' expectations [21].

While the implementation of electric aircraft would lead to a novel system involving people, procedures, facilities, and equipment. Airline practitioners would need to first identify the possible risk in the new electric aircraft system and consider the acceptable probability and severity of a hazard. Incorporating electric aircraft into the Safety Management System (SMS) is also required [22].

2.7 RESEARCH QUESTIONS

While electric aircraft possesses green-energy-related benefits such as zero CO2 emission, what are the research areas or themes that the industry or academia have studied? What were the specific research areas that have been important to make electric aircraft successful? While revenue or cash flow is the major driving force for practitioners to continuously improve their services and to be sustainable, what are perceptions of aviation practitioners regarding using or hosting electric aircraft? The authors defined two research questions as the following:

1. What research areas had been studied in relations to electric aircraft?
2. What were the major concerns affecting aviation practitioners when considering the usage of electric aircraft?
3. What are the possible safety concerns regarding the operation of electric aircraft?
4. How risk management can be applied to electric aircraft operation?

3 METHODOLOGY

3.1 CASE STUDY

For stage-1 of the methodology, the authors proceeded Case Study to collect qualitative data from existing body of knowledge. According to Naumes and Naumes [23], case studies could use one unique set of research projects to comprehensively extract useful information for a special research purpose. To answer Research Question 1 based on meta data, the authors applied VOSviewer to generate available themes and interconnected clusters for further analysis. To answer Question 2, the stage-2 of the study applied in-person interviews. Interview questions in the questionnaire are provided in the Appendix, which stemmed from literature reviews and focused on collecting the perception of electric aircraft from aviation practitioners.

3.2 VOSviewer

The VOSviewer software uses a smart local moving algorithm that identifies nodes and edges efficiently. This algorithm reiterates itself until a maximum level of optimization has been achieved when processing a large number of iterations on larger-sized networks [24] [25]. VOSviewer mechanism enables researchers to download and categorize documents for a quick data visualization and as a foundation for questionnaire to answer Research Question 2. Web of Science was used to download publications in the full-record format. These downloaded documents were then converted into .txt format for VOSviewer mapping process. VOSviewer is a program that uses Artificial Intelligence (AI) to review, analyze and extract qualitative themes, highlights or clusters available to researchers for a further interpretation [26] [27][28][29].

3.3 RELIABILITY & VALIDITY

While one of the purposes of this study was to examine consistency, authenticity, and truthfulness of the findings [30][31]. VOSviewer findings were incorporated in the questionnaire and delivered to practitioners for the validation, namely Delphi Technique [32]. The interview questionnaire of Research Question 2 was designed intentionally to capture a wide range of feedback, using open-ended questions and compared with the literature reviews after data triangulation [33].

4 FINDINGS

4.1 WHAT RESEARCH AREAS HAD BEEN STUDIED IN RELATIONS TO ELECTRIC AIRCRAFT?

Running the VOSviewer algorithm on the reference list, this research gathered revealed about 100000 words, and VOSviewer identified about 6000 terms from the data. Running the full counting of the terms generated Figure 1, which showed around 12 clusters such as "FAA", "TCCA", "aircraft", "battery", "case", "airport", "city" just to name a few, with the biggest cluster being the "FAA" a.k.a. Federal Aviation Administration and "TCCA" a.k.a. Transport Canada, together, they can be referred to as the regulators. The VOSviewer network visualization based on full counting is comprehensive, involving many sub-clusters that contain important information for the research.

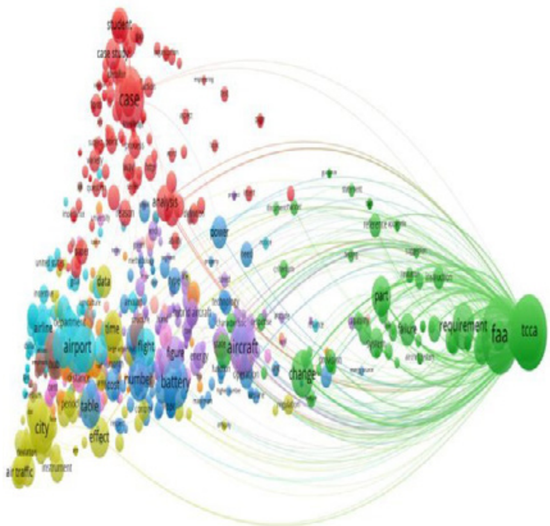

Fig. 1. Regulatory Bodies of Electric Aircraft Studies

The highlighted connection of "FAA" cluster with other sub-clusters in the network visualization is shown in Figure 2. Although the full counting of terms generated a rather big diagram, it can be observed that there were "case analysis", "aircraft specification", "service and maintenance", "project management" perspectives connected to the "FAA" cluster. Those connections identified by the natural language processing software taking the connections of key concepts across dimensions, expressed in clusters as parallel, could enable policy makers to make more practical analysis and decisions on the emerging technologies.

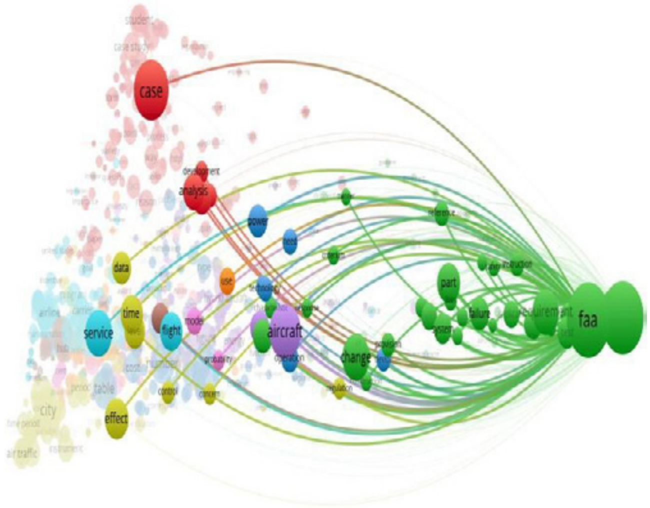

Fig. 2. FAA & Related Clusters of Electric Aircraft Studies

To further analyze, the "special conditions" of the electric aircraft were linked to the "FAA" cluster as electric aircraft is new to the FAA approval procedure via "special condition" (see Figure 3). This observation reflected on the importance of the specific Federal Register published in June 2021 for electric engines. To analyze further, there were enormous sub-clusters of "special conditions" for the electric aircraft development research. The links to the sub-cluster such as magniX engine design, continued airworthiness, mil-std (military standard), maximum transient, etc. These technical terms provided an informative outlook for the study to discover key areas in the development of electric aircraft.

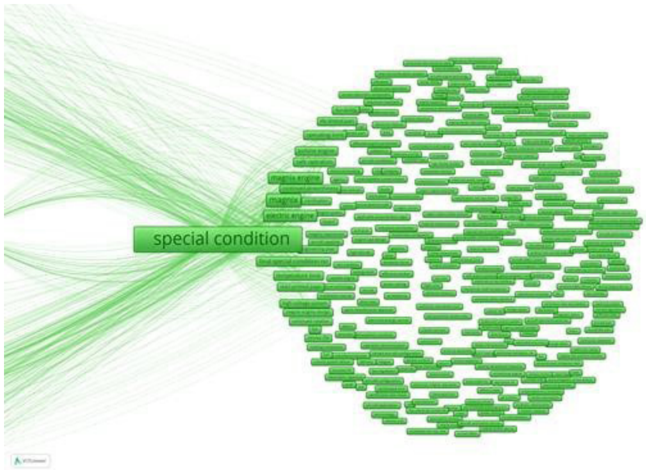

Fig. 3. FAA "Special Conditions" of Electric Aircraft Studies

In figure 4, a more concise natural language processing procedure was done. The result yielded eight (8) color-coded themes, with some sub-clusters of "battery", "case", "mass/ weight", "airports", "city", and "certification". A further analysis on "battery", which was one of the keys to develop of electric aircraft, connected to a series of key terms that provided researchers with insights into what needed to look for when developing and testing new battery technologies, such as the "acquisition cost", "battery charging schedule", "charge time evolution", "BPC" (battery plug-in chargers), and "battery swapping" (see Figure 5). This has been a functional way for the battery researchers to identify key areas for their future development.

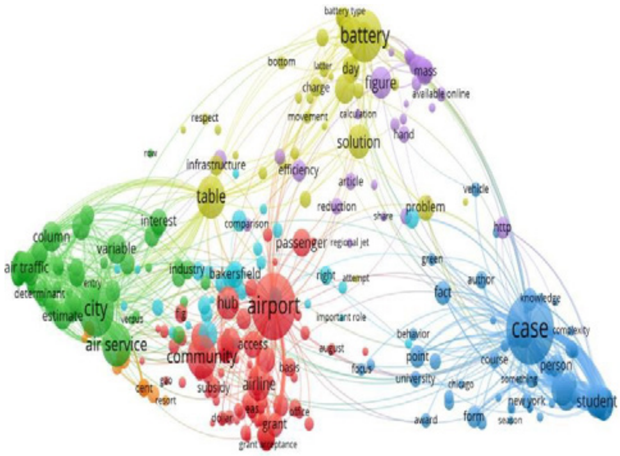

Fig. 4. Clusters of Related Studies of Electric Aircraft Studies

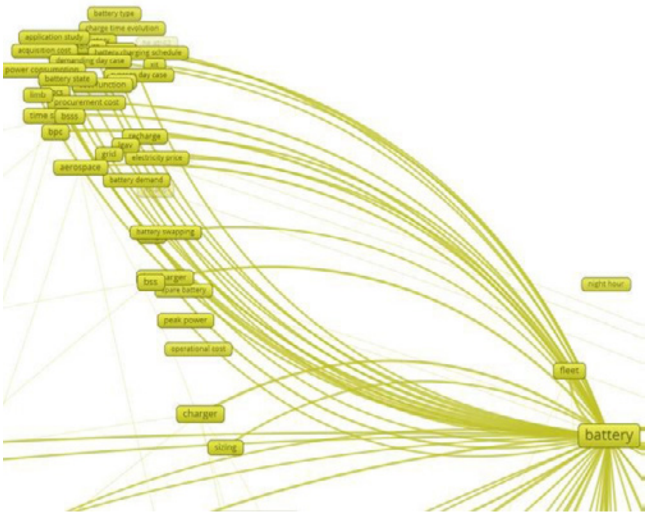

Fig. 5. Related Studies of Battery for Electric Aircraft Studies

Another observation the "battery" cluster was connected to was technical concepts (see Figure 6) including current energy-output methodologies of the electric aircraft industry including "electric aircraft", "hybrid aircraft", "hydrogen", "energy consumption", and "regional aircraft". Besides battery studies, another alternative green energy like hydrogen was also studied by scientists to reduce CO2 emission. There is no surprise that energy consumption or efficiency played an influential variable of the study.

The next cluster of interest was the policy sub-themes, as shown in Figure 7. These themes were under the main connection node of the "city", which referred to "airports", "traffic management”, “income”, and “Airline Deregulation Act (ADA)” involving governmental subsidies. There were significant terms related to the benefits of implementing the ADA’s Essential Air Service (EAS) program on electric aircraft, including “correlation”, “economic growth”, “employment”, “robustness”, etc. When considering electric aircraft, “ADA” and “air traffic change” reflecting on the “income” that connected to “city.” While “income” stood out, it showed that revenue is critical to cities when considering air services.

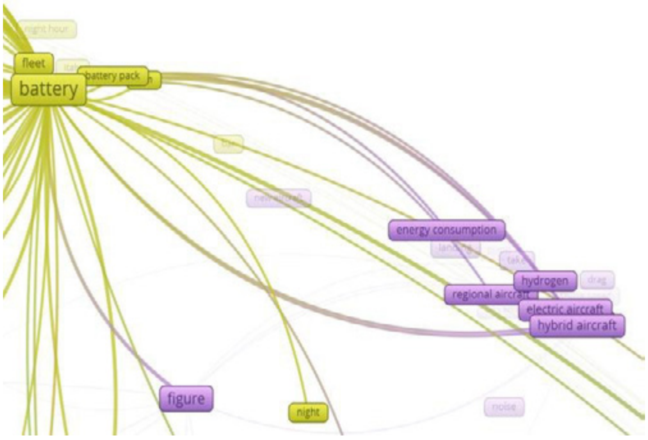

Fig. 6. Related Technologies of Battery

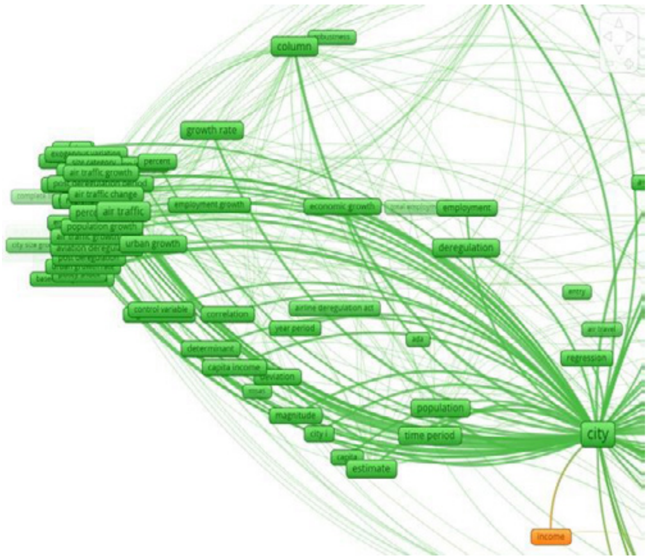

Fig. 7. Related Studies of “City” cluster

The last cluster of interest was the Essential Air Service. Notice that there were robust connections with the other clusters and terms of the “SCASD Grant” prevailed. Small Community Air Service Development Program (SCASD) Grant has been a program designed to assist smaller communities with their air transportation needs. The algorithm was able to pick up that co-occurrence in the data, that connected this program with terms such as “incentive package”, “grant application”, “small community air service”, “grant acceptance”, and “grantee.” This finding partially helped build up the foundation of the open-ended questionnaire (see Appendix) for interviewing voluntary aviation practitioners.

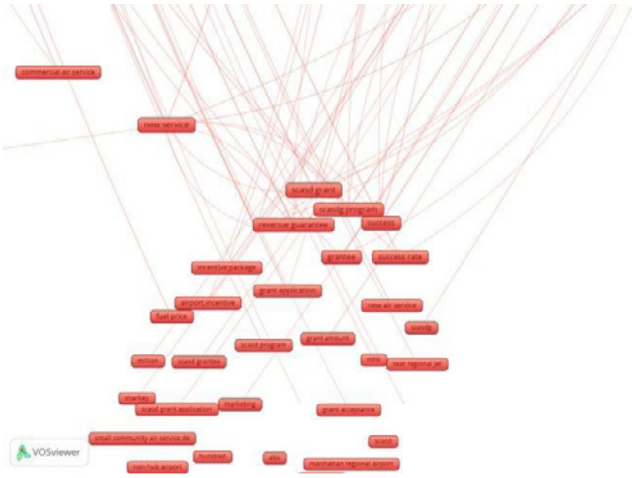

Fig. 8. "SCASD" Sub-clusters

4.2 WHAT WERE THE MAJOR CONCERNS AFFECTING AVIATION PRACTITIONERS WHEN CONSIDERING THE USAGE OF ELECTRIC AIRCRAFT?

The stage-2 of this study aimed to validate the findings from VOSviewer meta-analysis. Voluntary aviation practitioners were purposively selected, and in-person interviews were conducted virtually. One SCASD-subsidized regional air carrier was recruited to shed light on the concerns of the similar air service providers (see Table 1).

Interviewee A	Airport Manager, restoring commercial air service
Interviewee B	Airport Manager, EAS contractor
Interviewee C	Airport Manager, EAS contractor
Interviewee D	Airport Manager, EAS contractor
Interviewee E	Airline Executive, EAS contractor
Interviewee F	Airport Manager, EAS contractor

Table 1. *Voluntary Interviewees - Aviation Practitioners*

Cost, Subsidy and Green Energy. From an airport perspective, any services are important as operational scope and services meet community's needs underpinning development and economic growth. In the same vein, airlines need to be financially sustainable to serve specific areas, either a route that could generate sufficient profit on its own or receive subsidies to continuously survive. From feedbacks of aviation practitioners, some challenges and concerns are listed as the following:

Interviewee F brought a supportive perspective and was the only interviewee who was actively looking towards electric aircraft. As a city that was looking towards carbon neutrality and emission reduction, the airport had existing solar facilities, and was looking forward to adding more panels onto hangars and parking facilities. Interviewee F explained that as a major maintenance base of a regional air carriers using turboprop aircraft, it was likely that eventually the airport would be servicing electric aircraft. Like Interviewee D, this airport has been using AIP money for runway development projects and would likely use the SCASD grant in the future to study demand in the catchment area. When asked about future services, Interviewee F specifically supported 19-seaters such as Heart Aerospace ES-19, as 19-30 seat aircraft had worked sufficiently for this community throughout history.

Interviewee E, an airline manager, explained that aircraft were chosen based on the cost per available seat mile (CASM) and aeronautical capabilities. This made sense from a cost-benefit analytical perspective. While the airline had a deal with Eviation for 9-seat electric airplanes, interviewee E explained that there still seemed to be a cost disadvantage, even when accounting for fuel savings. Cost would need to be offset with additional subsidies, hoping that the Department of Transportation or other entities come to increase financial support for "green" technology adoption at the airport. Of course, electric aircraft had been recognized due to the advantage in speed performance over its current fleet of conventional, thus allowing for farther flights in the same amount of time. This observation was important for the operational scope of this airline, whose main competitor was ground transportation. Due to the confined space and weight of the aircraft, lavatories were infeasible. Thus, flight range and time should be carefully concerned or restricted for the sake of passenger comfort. By utilizing faster aircraft like electric aircraft, longer routes could be achieved and made the carrier more competitive against ground vehicles. The seat number at nine (9) was also crucial as this was the maximum allowable passengers to fly under 14 CFR Part 135, which permitted one ATP certified pilot to operate. As Interviewee D explained, EAS supported up to 36 trips/week for nine (9) seaters or fewer, or up to eighteen (18) trips/week at 30 seats or more. Aircraft with less than nine (9) seats or more than 30 seats were not eligible to be subsidized under EAS at this airport. However, this condition varies due to different cases or local community service needs.

Interviewee E also mentioned that the process of singing an EAS contract needed a high level of public involvement. Since electric aircraft were such a new technology, there may be apprehension to choose the eco-friendly aircraft. In this case, Interviewee E suggested that air carriers should still offer traditional air services to increase the chance when electric aircraft were not supportive by passengers within certain markets.

Fitness of Operation for Local Community. Interviewee D, like airport managers (interviewees A and C), was open to different services, but wanted to make sure it would appropriately fit the community's demands. Not too long ago, the airport switched from Cape Air (Cessna 402 9-seaters, Tecnam P2012 11-seaters) to SkyWest (CRJ200 50 seaters) under EAS, which was a significant shift. While the public input strongly indicated supports for the change to CRJs due to perception of lower risk, after it was implemented, issues became noticeable. Firstly, the larger jets offered less frequency or flexibility. Secondly, larger jets caused significant onsite flight delays due to problems (weather, schedule, manpower, mechanical issues) happened at the large hub airport. Often, the night "flight in" would become so delayed as the crews might not be rested adequately to operate the next "flight out" in the morning. Ultimately, when time came for the next contract, the public decided to forgo lucrative jet service in favor of returning to 9 or 11-seaters. With this in mind, Interviewee D noted that if an airline could provide reliable services with electric aircraft that fits the community's needs, it would be supportive and successful. In addition, effectively accommodating electric aircraft would require significant political support from the local citizens and could take a long time to initiate and come to fruition.

Conversely, Interviewee B's airport had SkyWest CRJ service under EAS contract which was just renewed for another three years. For this community, the larger jet service had been a better fit. Interviewee B indicated that it was because that local people tended to feel safer in jets over turboprops. Thus, Interviewee B would be hesitant to invite electric turbo-prop aircraft that offered far fewer seats than a regional jet, which could potentially jeopardize the airport's enplanements and airline revenue. However, Interviewee B did see the potential market of electric aircraft for other smaller communities.

Facility Renovation, Return on Investment and EAS. Interviewee A, who has been seeking to regain scheduled air services, was hoping for airlines to schedule flights to serve the adjunct communities. While Interviewee A was confident that sufficient demand did exist in the area for successful sustainability, airlines were reportedly hesitant to start service due to the lack of adequate terminal facilities per FAA FAR Part 139. This put the airport in a challenging situation because even if it was ready to invest in terminal faculties and install security measures, there was no guaranteed airline services.

Interviewee C, which had EAS service in place, was considering business expansion. While the demand was significant, this airport opted to expand service with a non-EAS airline in the early 2000s. After a $200K investment to renovate its infrastructure, including a baggage claim area and added holding space in the terminal, however, incumbent airlines cancelled flight frequency at the airport due to the unforeseen recession of 2008. As smaller airports have been extremely sensitive to expenditures while hoping to expand service, flight reduction caused substantial financial burden at this airport. They were hesitant to spend large amounts of money on upgrades if there were no guaranty to attract airlines. As a result, when considering housing electric aircraft, none of the above two interviewees were intending to revamp infrastructure to support electric aircraft.

4.3 WHAT ARE THE POSSIBLE SAFETY CONCERNS REGARDING THE OPERATION OF ELECTRIC AIRCRAFT?

Leading technology could significantly reduce the workload of pilots. However, more training is needed for pilots to understand operating such equipment. Flight training is a systematic process including ground knowledge, simulation, and flight courses. Airlines and flight schools are required to develop additional hierarchical training programs for electric aircraft. The implementation of assorted training hardware and software could increase the cost of airline's budget.

Maintenance is another concern about the deployment of electric aircraft. The aviation industry has grown rapidly; one of the significant elements of aircraft's operating cost is maintenance [34]. It is important to control the rate of aircraft downing events since aircraft will not make value if it is not in operation [35]. The type, age of the aircraft, and the point of time in the maintenance history also affect the magnitude of both labor and material cost at each maintenance event [36]. Nevertheless, some airports cannot provide such facilities, equipment, and materials for the maintenance process. Airlines will need to dispatch aircraft into another airport for the maintenance process. Proper aircraft maintenance management could significantly reduce the cost for airlines. It is required to have a detailed cost and revenue estimation for airlines to consider the implementation of electric aircraft.

The development of the aviation industry made customers have various choices on selecting the proper flight. While airlines have their preferences of fleet management, such as technical and economic aspects, passengers also have their concerns. Travel price, time, comfortability, luggage per passenger, and service quality are some major concerns for air travel [37]. The implementation of electric aircraft could save passengers' travel time, but the monetary cost for passengers is still undetermined. Aircraft powered by renewable resources, such as electricity, could significantly reduce the operational cost compared to fossil fuel energies. However, the construction of paired facilities, such as battery replacement fixtures and maintenance hubs, are undetermined. Passengers' expenses would rely on the cost of developing electric aircraft's assorted facilities.

4.4 HOW RISK MANAGEMENT CAN BE APPLIED TO ELECTRIC AIRCRAFT OPERATION?

Airline practitioners must develop a proper risk matrix and understand the severity and probability of causing such risks. Creating such a system safety tool either eliminates the risk or reduces it within the acceptable level.

As the risk matrix could be slightly different once it fits in certain circumstances, airlines practitioners need to evaluate their organization and develop a suitable risk matrix.

Likelihood \ Impact	Negligible	Minor	Moderate	Significant	Severe
Very Likely	Low Med	Medium	Med Hi	High	High
Likely	Low	Low Med	Medium	Med Hi	High
Possible	Low	Low Med	Medium	Med Hi	Med Hi
Unlikely	Low	Low Med	Low Med	Medium	Med Hi
Very Unlikely	Low	Low	Low Med	Medium	Medium

Fig. 9. Risk Matrix Example by ARMS Reliability

Figure 9 above shows an example of a risk matrix. Airline practitioners would first need to evaluate the likelihood of a risk and the impact of the event. Once the risk is assessed, the severity of the risk can be determined.

```
C = [2 3 3; 1 2 3;1 1 2];
V = [1 2 3;2 4 6;3 6 9]
ax=axes
hold on
[X,Y] = meshgrid(1:size(C,1),1:size(C,2))
h = imagesc(X(:),Y(:),flipud(C))
cmap = [0 1 0;1 1 0;1 0 0];
str = sprintfc('%d',V(:))
text(X(:),Y(:),str)
RowLabels = {'unlikely','possible','very likely'};
ColLabels = {'negligible','moderate','severe'};
set(gca,'xtick',unique(X),...
    'ytick',unique(Y),...
    'yticklabels',RowLabels,...
    'xticklabels',ColLabels)
cb = colorbar(ax,'location','southoutside')
set(cb,'ticks',[1.3 2 2.7],...
    'ticklabels',{'Low','Medium','High'},...
    'ticklength',0)
box on
set(ax,'layer','top')
colormap(cmap)
```

Fig. 10. *Risk Matrix code via MATLAB*

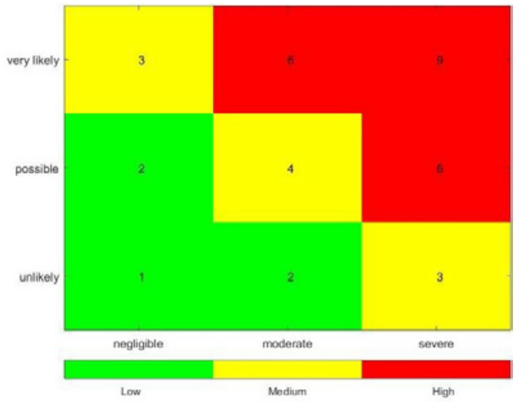

Fig. 11. Risk Matrix via MATLAB

Figure 10 above shows a simple example of developing a risk matrix using MATLAB. The sample given above (Figure 11) is a three-by-three risk matrix. Practitioners would be able to modify the risk matrix based on the system evaluation and change the risk level based on the requirement.

The first step for the system safety procedure would be to design within the minimum risk. Engineers need to focus on individual item first, such as battery. Minimizing the risk during the design process is less expensive than post-catastrophic compensation. The second step is incorporate safety devices. It is mandatory to have additional safety devices implemented to reduce the risk if some risk cannot be eliminated during the design process. The third step is to provide warning devices. Providing adequate warning devices can reduce the risk of passengers' injury practitioners' injury during their travel and operation. The fourth step is the development of practitioners' training and procedures. Adequate training and practice are needed for the electric aircraft system. The final step is risk acceptance. Risk acceptance depends on how much the risk can be accepted after the evaluation. For example, if the risk is significantly low, it is feasible for practitioners to accept the risk.

4.5 DISCUSSION

The result of VOSviewer analysis showed interconnection among clusters. The finding also set a baseline for interview questions conducted with the six voluntary aviation practitioners. While battery technologies or the electric aircraft certificate process were top priorities to manufacturers and the government, concerns on the practitioners' side were different. But each interviewee provided feedback that was closely involved with technologies from the user's standpoint, such as safety, frequency, cost, and flight range. Airports and air carriers primarily focused on the demand of the communities embracing revenue-driven operations. Cost-benefit analysis has been critical while local public voice would be imperatively important. Another highlight is that both EAS and SCACD grants could benefit small communities who needed air services. Airport managers were intrinsically familiar with the needs of their community and understood how air service should operate. While some practitioners were looking for new, traditional services from air carriers without substantial investment to facilities, others preferred "round-robin" style flight between cities in the state. An example was a flight operated from Phoenix Mesa with stops in Bloomington-Normal and returned to Phoenix-Mesa. While some practitioners were not interested in anything less than 50 seat services, others suggested various options of air services.

Areas with more developed carbon neutrality programs or higher percentages of renewable resources would impact the initial cost of program initiatives. While all interviewees mentioned operational costs and governmental subsidies, the Essential Air Service (EAS) program would be crucial to keep the remote air services alive. Due to the need for continuous technology upgrades and corresponding airfare could make EAS contractors using electric aircraft less competitive than EAS airlines using traditional fuel-powered aircraft if a reasonable airfare, flight frequency, range and time, and safety could not be secure.

5 CONCLUSION

This study analyzed how electric aircraft could fit the commercial air service system. A case study was created to collect research themes and clusters from the existing body of knowledge followed by collecting practitioners' feedback and perception of incorporating electric aircraft under EAS or SCASD grant programs. Based upon first-step analysis and themes generated by VOSviewer, questions directed towards voluntary practitioners were developed.

Aviation practitioners focus on operational cost, market share, and local demands. While EAS subsidizes air carriers, airports would need a guaranteed service before investing in facility innovation to host electric aircraft. Facility investment is unrealistic by the time of this study due to market uncertainty as they indicated little to no benefits of investing in facilities to house electric aircraft soon.

While the current EAS grant covers various aircraft from Pilatus PC-12 (8 seaters), Cessna 208 Caravan (9 seaters) to Bombardier CRJ 200 (50 seats), there is certainly a market niche for electric aircraft. Interviewees mentioned that it would take significant push from the public and industry. They also believed that electric aircraft could be a part of the national airspace system (NAS), yet types of electric aircraft must be specified for different communities.

According to practitioners' perspectives, electric aircraft serve small but in-demand communities for cost-effective purpose. Aircraft must be reliable, safe, suitable for the specific operations and passengers. Besides, electric aircraft are expected to show equivalent cost per available seat mile (CASM) vis-à-vis that of traditionally powered aircraft, including significant aeronautical capabilities such as flight time and range. With this in mind, if an airline is expected to use electric aircraft, EAS shall be awarded to offset the overall operational cost. One example of sustainable operation was one interviewee's operation of four (4) Britten-Norman Islander aircraft compared to 70 Cessna 402 and 24 Tecnam operations. Britten-Norman Islanders proved to have a significant advantage operating out of airports in the Caribbean. This air operator showed willingness to adopt electric aircraft provided all necessary conditions are met.

Yet it is also important to note that some aircraft do not fall under the umbrella of Essential Air Service and EAS is on a case-by-case situation. The rule of thumb is that air carriers under EAS providing services to remote communities would operate 50- seaters or smaller electric aircraft to maintain flight frequency, be cost-effective and reliable, and mitigate impact due to unforeseen delays at hub airports. This operational specification requires scientists and engineers to accomplish and continuously devote to improving electric aircraft.

6 FUTURE STUDY

From the researchers' standpoint, VOSviewer natural language processing software was able to guide through literature related to the research and development of electric aircraft. However, many researchers and scientists were unfamiliar with the operational nature of air carriers. Thus, the best fit for their product market could be general aviation. A follow-up study should focus on the non-commercial general aviation industry users, including flight training institutes.

APPENDIX: OPEN-ENDED QUESTIONS

1. What is the history of commercial service at your airport/airline, and how has it been operated?
2. Per question 1, have the operation (pass or current) been subsidized? If so, what subsidy program(s) was/were used?
3. What is the 5-year plan to attract or expand Part 135 or Part 121 commercial air services at your company?
4. Can provide your familiarity with electric aircraft?
5. What would be the pros and cons of accommodating/operating electric aircraft at your airport/airline?
6. Knowing Electric Aircraft are under development, what your airport/airline would expect to handle the change of operation?

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WOMEN IN STEM - A SUSTAINABLE APPROACH BETWEEN BEST PRACTICE AND CHALLENGING STRUCTURAL LEVELS

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Key words: Women in STEM, Best Practice in STEM, Sustainability and Promotion of women in STEM, Career orientation for women, Career-Building Elements, Hessen-Technikum

ABSTRACT
Why is the number of female students in STEM studies still not increasing at a meaningful rate or even declining? The cause is not a lack of knowledge and talent. In the opposite: female STEM students complete better degrees in the standard period of study than their fellow male students.

This is not only a loss of talent, valuable knowledge and experience it also embodies gender inequality. The authors trace the significant and often-underestimated impact of heteronormative gender stereotypes, which are reflected in the self-perception of departures and in universities structures. The problem is systematic and socially constructed. This paper aims to shed more light onto these structures and phenomena associated with them. The authors review the experiences of the successful program Hessen-Technikum and the planning of the Career-Building Elements support measure for their sustainability in terms of gender equality. Both programs – ambitious and suitable designed - can be an example for a response to political and economic buzzwords such as shortages of skilled workers and usage of human resources. Bentrup and Gruner pose questions about long-term success of programs like those presented in the paper. How you could or even should define such success in terms of sustainability?

Keywords: ***Gender Equality, Sustainability, Curriculum Design***

1 INTRODUCTION

When people talk about the problem of too few female students in STEM fields of study, the term shortage of skilled workers is usually not far away. More distant seems the term gender (in)equality. For years now, the shortage of skilled workers brings worry lines to the foreheads of human resource experts and politicians. Especially in technical courses and professions, this trend cannot be overlooked. The number, or lack thereof, of female students is receiving particular attention in this regard. The number of women in the so-called STEM professions has been stagnating at a low level for a long time (these figures are not transferable to the global context; rather, in the form presented here, they represent a specific feature of so-called Western industrialized nations. Sexist discrimination, on the other hand, among other discriminations, is a structural disadvantage that very much embodies a global phenomenon). Fewer female students are graduating with a STEM focus, fewer female students are graduating with a degree in technology, and female high school graduates are less likely to seek technical training in contrast to their peers. By no means because of lacking skills or interest. Numerous studies and research show, including most recently the Organization for Economic Cooperation and Development (OECD) in 2019 the situation is complex and has not yet been explored in its breadth as far as causation. What is known and partly acknowledged is the lack of appropriate role models and visibility for female engineers, mathematicians and scientists.

The problem is systematic and socially constructed. This paper aims to shed more light onto these structures and related phenomena. A first step substantiates these phenomena in terms of data collected at Darmstadt University of Applied Sciences (h_da) and gives insight in theoretical backgrounds. A second step presents two best practice programs of

Darmstadt University of Applied Sciences that deal with the promotion of young women in the STEM sector: Hessen-Technikum and Career Building Elements. Evaluations and practical experience support these programs with current figures. In a final step, the outlook, we discuss the factors necessary to promote women sustainably in the STEM sector.

2 DATA FROM GENDER EQUALITY MONITOR AND THEORETICAL BASE

H_da`s (Darmstadt University of Applied Sciences) Gleichstellungsmonitor (Gender Equality Monitor) provides us with figures on the gender quotas of students, their courses of study, degrees, dropout rates and much more (Haffner/Wissel 2020). Beyond that, the regular collection of this data is the basis of being able to trace and anticipate developments.

In the semester 2018/19 roughly 17.000 students study at h_da, 63 % were male and 37 % female. Looking more closely into study courses the gender inequality is striking and still not discussed enough. Courses of study like Informatik (Computer Science) or Elektro- und Informationstechnik (Electrical and Computer Engineering) counted 14 - 15 % female students. Maschinenbau und Kunststofftechnik (Mechanical Engineering and Plastics Technology) bring up the rear with 10 % female students. When discussing gender inequality we have to include both genders (In a next step, we must think beyond the binary gender order to include all genders. Hence, data collection has to get more diverse). The study course Soziale Arbeit (Social Work) has also a gender lack – just 25 % of students are male. This fact receives even less attention.

It is instructive to delve a little deeper into the topic of female students and STEM programs. Statistically, female students in STEM graduate with better degrees and more often in the standard period of study (in addition, the high dropout rate in STEM programs in general is an issue that needs more attention.). The civil engineering degree program provides an impressive example. In 2016 among all students 34 % were female, 2018 the number shrank to 28 %. Other degree programs show less dramatic decline, overall, there is no indicator for an increase of more than 1 or 2 % any time soon. In order to lift the numbers out of abstraction and understand their genesis, the following part introduces, in broad strokes, theoretical concepts that are indispensable for a broader and deeper understanding.

One concept that describes the barriers women face in the STEM sector is heteronormativity. Heteronormativity refers to a worldview that postulates heterosexuality as the social norm. The premise is a binary gender order in which anatomical/biological sex assimilates with gender identity, gender role, and sexual orientation (Hartmann/Klesse 2007). It connotes women with care work and men as breadwinners (Nave-Herz 2013). This gender order is a hierarchical order in which care work is systematically devalued. In constantly repeating processes and gender performances, the constant doing (doing gender) naturalizes gender stereotypes and thus makes them invisible. Women, who aspire to careers, especially STEM careers, experience ongoing heteronormative sexism in their professional lives. Additionally, in societies where family subsidiarity is encouraged, they experience a double burden. In addition to pursuing a career, women are structurally encouraged to take on family care work and, on average, take more parental leave than men (Becker-Schmidt 2007). This leads to a gap in their careers and is rarely recognized statistically as a systematic problem (Bereswill/Neuber 2010). Old Boys' Networks, Leaky Pipeline, and Glass Ceiling: these are not only frequently used buzzwords, moreover they are expressions of discrimination and disadvantage. They describe the structural barrier that women have to overcome once again after graduation as soon as they enter their profession.

Raewyn Connells theory of hegemonic masculinity explains these phenomena as well. White men, in particular, Connell argues, gain career advancement more quickly and directly through privilege and are less likely to experience discrimination (Connell 2015). Bereswill too postulates, that gender relations and class relations are for a matter of fact transforming, but male domination is never going to be exhausted. (Bereswill/Neuber 2010). The STEM sector is not excluded from this issue. Sustainable support of women can thus not happen through the participants themselves, or through the relentless efforts to keep support measures running, but is dependent on the structures of systems in which they take place. Accordingly, when choosing a course of study or a career, people tend to fall back on what is known and familiar: media and cultural practices represent "classic" female stereotypes more strongly. Other barriers that have a strong impact are, in particular, the male image of technology and the associated technical and professional culture in our society. According to Eichler, Fuchs and Maschewsky-Schneider, this phenomenon is a form of gender bias and is referred to as androcentrism (Eichler/Fuchs/Maschewsky-Schneider 2000). These barriers are structurally established and have long since ceased to be individual experiences and perceptions of women. The effects of these barriers manifest ultimately in the fact that many female school leavers simply do not trust themselves to study a STEM subject.

The transition from school to university proves to be a particularly precarious phase. Studies show that uncertainty about the right choice of course of study and future career is particularly high at this time (Driesel-Lange 2011, Oechsle 2009). On the one hand, an overabundance of possibilities about study and career options inundates school leavers. On the other hand, they find it difficult to pick out the facts that are relevant to them from this jumble of potential sources of information and to relate them to themselves, their abilities and interests. Instead of considering a variety of options, they then very often make their decision by choosing "the familiar" and orienting themselves to familiar job profiles, especially in their immediate environment: mothers, fathers, siblings or friends (Gisbert 2001, Oechsle 2009). Once they arrive at university, many students discover after the first few semesters that they had imagined something different or that their studies and career profile do not match their expectations and abilities, and they drop out. High dropout rates are characteristic of STEM subjects in particular and can be attributed not least to a lack of information and misconceptions about the course of study and the profession (Heublein/Wolter 2011). The fact that many resources are lost here is beyond question, as is the fact that many young people, but especially women, do not find their way into STEM subjects in the first place because they lack role models, practical information and experience in the field.

Finding and establishing new ways of orientation that combine both - practical experience in occupational fields and at universities - is therefore one of the keys to facilitate young people to make their life choices and to provide business and society with sufficient numbers of suitable skilled workers.

3 BEST PRACTICE

3.1 HESSEN-TECHNIKUM

Hessen-Technikum is a technical and scientific orientation program for prospective female students at the transition from school to university and offered at all state-run Hessian universities of applied sciences with STEM degree programs. Through the combination of company internships and university experience, the Hessen-Technikum precisely aligns with the practical orientation of Universities of Applied Sciences. Hessen-Technikum was developed and piloted at h_da from 2013-2018. From August 2018 to March 2021, the program was expanded to the other Universities in Hesse (Frankfurt University of Applied Sciences, Fulda University of Applied Sciences, RheinMain University of Applied Sciences, Technische Hochschule Mittelhessen of Applied Sciences). The coordination office continues to be located in Darmstadt under the direction of Prof. Dr. Yvonne Haffner along with one administrative coordinator. However, at each of the five locations, an additional operational coordinator carries out the Hessen-Technikum.

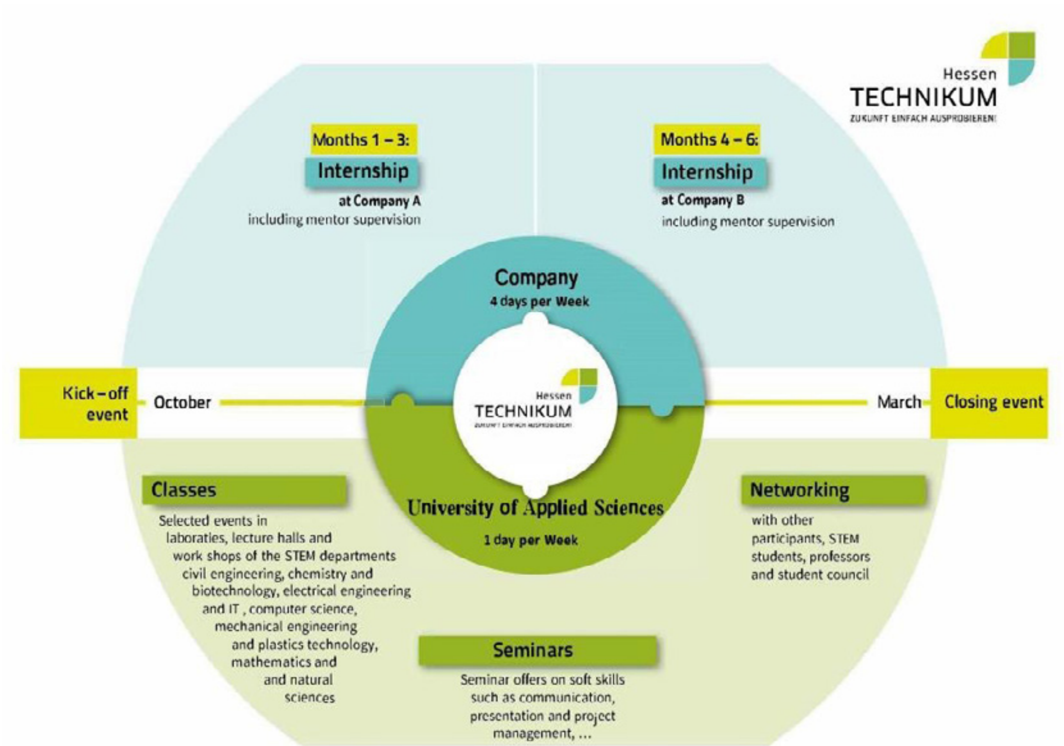

Fig. 1. Procedure Hessen-Technikum

With almost 130 graduates, the total number of participants reached triple digits. A recent evaluation (2022) of former participants confirms both previous program evaluations and current scientific conclusions. It shows that before the participation at Hessen-Technikum, the participants are very uncertain about their choice of study, that they have no concrete ideas about STEM courses and that over 70 % doubt that they will be able to complete a

STEM course. However, 95% of the former participants are currently studying. Over 90% have taken up STEM studies. Just as many have chosen the course of study because of their interest in the subject and because of the content. Thus, it is indisputable that after Hessen-Technikum, the participants have concrete ideas about their studies and careers and it strengthened their professional self-concept. These data are similar to numerous studies that have researched reasons for the low rate of women among students in STEM subjects, unanimously concluding that "technology deficits" among young women are not what prevent them from taking up STEM studies. Rather, it is the male connoted image of technology, the male-dominated technology and professional culture, and the associated structural barriers for women in this professional field that prevent young women from taking up studies in these fields.

In addition, the Hessen-Technikum locations have so far concluded 146 cooperation with companies in the STEM industry. 40 % of the alumnae still maintain in contact with their internship companies. Almost one fifth of the alumnae have even entered into an employment through Hessen-Technikum cooperation companies. The evaluation shows, that 91% of the participants are (very) satisfied with their current occupation. 88 % rate the role of Hessen-Technikum as (very) high. 96 % would participate in the Hessen-Technikum again.

Overall, 96 % participants share the opinion that Hessen Technikum was the right decision for them and helped them with their career orientation. They now have the confidence to study STEM subjects and can certainly imagine working in this field later. The data also indicates that Hessen-Technikum participants are less likely to drop out.

In fall of 2021, the statewide expansion and funding via the European Social Fund (ESF) ended. From 2022-2025, Hessen Technikum will be funded by the Hessian Ministry of Science and Arts (HMWK) with 1.6 billion Euros. Darmstadt University of Applied Sciences is once again the leading university. In the new funding period, the program will focus on acquiring more first-generation academics. By the end of 2025, five subprojects will more precisely address first-generation academics and women from more diverse socio-economic backgrounds.

3.2 CAREER-BUILDING ELEMENTS: FOCUS ON FEMALE STEM STUDENTS AND STEM-ENTHUSIASTIC FEMALE PUPILS

Since March 2021, Career-Building Elements is in its conceptual phase. The ambitious program is a collaboration between the university alliance HAWtech and Femtec. The HAWtech University Alliance for Applied Sciences (https://www.hawtech.de/) is an association of leading technical universities in Germany. A total of around 64,000 students study at the participating universities, consisting of Aachen University of Applied Sciences, Berlin University of Applied Sciences, Darmstadt University of Applied Sciences, Dresden University of Applied Sciences, Esslingen University of Applied Sciences and Karlsruhe University of Applied Sciences. The proportion of female students is between 27 % and 39 %. This varies greatly from course to course and the number is lowest in STEM subjects.

Femtec`s goal includes promoting the next generation of women for careers in STEM.

Career-Building Elements is planned as an innovative and custom-fit program for STEM enthusiastic female high school and college students. Already female pupils should be addressed by the various elements of the program. Career Building Elements opens up the opportunities and possibilities for targeted advancement with technical degree programs. “Understanding schools as places that can support the process of social and societal change also means confronting stereotypical ideas of career profiles there and doing something to counter them. After all, the statistics on female students in STEM subjects clarify the extent of the influence of gender stereotypes.” (Gruner 2022, p. 42, translation by author)

The implementation of gender equality and the realization of equal opportunities represent the agenda of Career-Building Elements. In this regard, the program pursues an intersectional approach. Intersectionality, as a concept and perspective that analyzes and explores the multiple possible intersections and entanglements of discrimination categories. Gender equality in terms of an intersectional perspective functions as an overarching and intersecting theme that challenges eurocentrism in relation to internationalization, global teaching, and collaboration. Thus, the inextricable link between the issue of gender equity and issues such as migrant background or students who come from a non-academic family is evident. Accordingly, Career-Building Elements stakeholders have made it their mission to pay attention to gender diversity.

Career-Building Elements is dedicated to these topics. Designed around four pillars, each of which influences the other and gives room for synergies. As a promising and sustainable aspect of strengthening gender equality, the program ranges from school to university to career entry. The aim is to inspire und support female pupils to take up STEM courses and to encourage talented women to take up STEM studies. Entering a degree program at a university of applied sciences, especially a male-dominated discipline with a strong male connotation; women often perceive this experience as difficult and demanding. Career-Building Elements aims to counteract the isolation of individual female students, which requires opportunities for exchange and networking to share experiences, tips and ideas. The programs wants to support and accompany career entry, especially in science and business. Related to the sustainable development goal number five “Achieve gender equality and empower all women and girls” the representation of (gender) diversity also in STEM industries has a high relevance as a societal goal (https://sdgs.un.org/goals/goal5). Increasing the visibility of women in STEM industries will send a strong signal and serve as a role model. “Strong networks and learning and developing (soft) skills equip female STEM graduates with everything a leader with a sustainable and innovative career profile in science and business should have. In this way, they become players and role models for the necessary digital and green transformation.” (Gruner 2022, p. 40, translation by author).

Career-Building Elements focuses on companies with a promising and sustainable profile. A future of prosperity and security is only possible if many people and different social groups can participate in shaping this very future, formulate, and discuss goals together. “Why is this important? Thinking and acting from multiple perspectives has the great potential to fill blind spots with knowledge and experience. Everyone benefits from this - living commitment to diversity and promoting young talent - to address the issues of the present and the future together.” (Gruner 2022, p. 44, translation by author).

4 DISCUSSION AND OUTLOOK

Numerous programs, like mentoring or initiatives and events on and off campuses are focusing on female pupils and students to create and/or to nourish their interest in STEM. By no means just recently. To encounter contemporary and future questions and challenges it seems the knowledge about lacks of gender equality (to be included: race and class) are not sufficient. Programs like Hessen-Technikum show major success (see 3.1) still the number of female students in STEM studies merely move into the intended direction.

Women as `the unused human resource` is a common term to answer shortage of skilled workers. However, why are numbers of female students in STEM improving so slowly or even moving downward?

If we study the statistics, there is no indication that programs like Hessen-Technikum and Career Building Elements will become obsolete even in the medium term. What comes to the surface? They represent a symptom treatment. The symptoms are the low numbers of women in STEM subjects and subsequently in STEM professions, above all in management positions in economic sectors, which have an enormous influence on our societal national and international development. However, we should recognize that symptom treatment could only promise a short-term relief. Thus, it seems inevitable to recognize and act on the recognition that we have to deal with the causes, the roots of the problem - even if it means greater effort for some of us more than for others. Sustainability in terms of advancement of female pupils and students in STEM only arises throughout awareness of the above-mentioned phenomena and institutional implementation into the structures of polytechnic universities.

Undeniable is the power, success and necessity of programs like Hessen-Technikum and Career-Building Elements. As long as the presented challenges of hierarchical gender stereotypes are insufficiently dealt with in other fields and structures of educational institutions from kindergarten to university and a debate in society as a whole is just beginning to sprout - programs like Hessen-Technikum and Career Building Elements are indispensable. As an important part of getting a necessary change rolling, we have to define them as starting points for broad and diverse engagement in the field of gender justice. A way in which universities see themselves fulfilling their societal responsibility.

To address existing gender bias in disciplines, institutions and society is still rare. How does academic self-understanding especially in STEM departments and gender stereotypes in society correlates with lower female student rates in STEM? We have to be aware and include those research results into concepts to enhance female student rate. Not exclusively as an end in itself but with more foresight as a necessary foundation of a democratic society, sustainable, self-critical and defensible.

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USING THE COMMUNITY OF PRACTICE MODEL TO SHAPE APPROACHES TO EDUCATION FOR SUSTAINABLE DEVELOPMENT ACROSS DISCIPLINES IN A TECHNOLOGICAL UNIVERSITY CONTEXT: A ROUNDTABLE PODCAST

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ABSTRACT

This roundtable discussion podcast comprises eight colleagues engaged in reflective discussion of their shared experiences of being members of SDG Literacy.ie, a Community of Practice (CoP) first established in TU Dublin in 2020. This CoP focuses on and promotes the enhancement of Sustainability Literacy among student cohorts as one measure to be employed in strengthening Education for Sustainable Development (ESD) in line with the broader strategic aims of the university. Harvey et al. (2021) in a case-based paper which includes examination of the CoP discussed here conclude that teaching and learning innovation took place as a consequence of the resource-sharing, idea-generation and overall peer support that CoP members experience. The voices you will hear in this podcast discussion represent the interdisciplinary SDG Literacy academic community who all share an interest in the sustainability domain and are acutely aware of SDG4.7 which focuses on ensuring all learners acquire the knowledge and skills for sustainable development by 2030. Discussion themes include (i) our shared understanding of ESD, (ii) how membership of SDGLiteracy.ie shaped our Teaching, Learning and Assessment (TLA) approaches in relation to ESD, Sustainability Literacy and Authentic Assessment, (iii) how membership of SDGLiteracy.ie shaped our broader personal and professional development (research, collaboration, output etc.) and (iv) our future plans in relation to ESD and the CoP model. The podcast transcript has been annotated through footnotes to direct the listener/reader to further reading on the various topics that emerge in the discussion.

Keywords:* *Sustainability, Sustainability Literacy, SDG, Education for Sustainable Development, Community of Practice, CoP model, Authentic Assessment.

Note:* *The podcast from which this transcript has been made forms a supplemental file with this paper.

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Link to Recording: PS2022 Podcast Recording

TRANSCRIBED DISCUSSION

Olivia
Okay, you're very welcome to this roundtable discussion which we are recording for submission to the Polytechnic Summit 2022, taking place in Hochschule Darmstadt. Our discussion will focus on innovation in curriculum and pedagogy under the sustainability thematic. I'm joined today by seven of my fellow colleagues and coauthors from Technological University Dublin. As you will hear in the podcast, we work in different disciplines in the university[1]. We teach diverse modules. Yet, we share an interest in education

1 www.tudublin.ie

for sustainable development[2] and the enhancement of sustainability literacy for students and for our colleagues[3]. We were fortunate to receive Impact funding[4] which we have utilized to develop a community of practice (CoP)[5] SDGLiteracy.ie. In line with academic literature, we understand a community of practice to be a group of people who share a concern or passion for something they do and learn how to do it better as they interact regularly[6]. We are coming together today to discuss our individual and shared experiences of being founding members of this community of practice, and to reflect on the tangible outputs that have resulted from involvement in this group. Our transcribed discussion will be annotated to build connections between our experiences and existing theoretical discussion on communities of practice. We will also utilize annotations to signpost additional resources relating to our discussion today. My name is Dr. Olivia Freeman and joining me in this podcast are Dr. Cormac McMahon, who is currently leading on sustainability in the curriculum for TU Dublin, Alacoque McAlpine, lecturer in Supply Chain Management, Odette Gaubaudan, lecturer of French, Dr. Lucia Walsh, lecturer of Entrepreneurship and Business Sustainability, Sheona Foley lecturer in Culinary Arts and Food Technology, Dr. Patrice Behan, senior lecturer in Chemical and Pharmaceutical Sciences and Shaun Ferns, Education Model Project Team Leader. So, I will get started and perhaps I might first ask Cormac, to provide a little bit of background to this particular CoP, and to share with people listening the reasons why sustainability is now a strategic pillar for the university, and something we all feel very strongly about.

Cormac

Sure, thanks, Olivia, I guess, you know, higher education has been seen very much as a key instrument in the drive to pursue sustainable futures. And that dates right back to seminal reports, like the Club of Rome Report[7], the Brundtland Report[8] and slightly more recently, we had the "Talloires Declaration"[9], which really sort of placed sustainability agenda, education was seen to have a dual mandate, if you like, it was a goal in itself to achieve better, higher quality, more inclusive education. But at the same time, it was seen as a catalyst to achieve other elements of sustainability. And we see that in the UN Sustainable Development Goals[10] or the "Global Goals," as they're called, where SDG 4 is really all about education[11]. But it's also seen within the framework of those sustainable development goals as a

2 See Cebrián G, Junyent M, Mulà I. (2020)

3 Bianchi et al. (2022) - GreenComp identifies a set of sustainability competences to feed into education programmes to help learners develop knowledge, skills and attitudes that promote ways to think, plan and act with empathy, responsibility, and care for our planet and for public health.

4 IMPACT is funded by the National Forum for the Enhancement of Teaching and Learning in Higher Education under the Strategic Alignment of Teaching and Learning Enhancement (SATLE) stream.

5 See Wenger, E, (2011).

6 See Lave and Wenger, (1991).

7 https://www.clubofrome.org/publication/the-limits-to-growth/

8 See Keeble, (1988).

9 https://ulsf.org/wp-content/uploads/2015/06/TD.pdf

10 https://sdgs.un.org/goals

11 By 2030, ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship and appreciation of cultural diversity and of culture's contribution to sustainable development, https://unstats.un.org/sdgs/metadata/

catalyst for other goals within the SDG framework, if you like. And I think as a result of that, TU Dublin in its inaugural strategic plan, recognize the centrality of the UN Sustainable Development Goals, and its new strategic intent to 2030 is really written through the lens of the SDGs. One of the specific KPIs in the strategic content to 2030 in TU Dublin is to shift away from having maybe pockets of excellence in sustainability across the university to an approach where all programs, that's academic, education and research programs, will have learning outcomes related to sustainability. So that's a massive shift away from just having those pockets of excellence as we might have had in the past to having a much more universal approach, where we can hand-on-heart say that our programmes are aligned to the principles and values of sustainable development. And I think in recognition of the sheer enormity of that particular KPI, a number of us in the room here who've had an interest in sustainability, either through our teaching or maybe personal interests, recognize the need to make sure that both our students and our staff are sustainability literate[12]. So we set about forming this community of practice, albeit with some help and support from National Forum and HEA funding. It's really allowed us to come together and explore ways in which we can raise the level of sustainability literacy within both our staff and student cohorts. And really the community of practice that has emerged since then has gone on to develop a wide range of activities and initiatives. So I'm delighted to hand back to you, Olivia, to engage in this discussion with our colleagues.

Olivia

Thanks, Cormac, that's really interesting. Good to have, I think, a background in terms of where this community of practice sits in the bigger university context. The community of practice is called SDGLiteracy.ie[13] So, I might ask Alacoque to explain a little bit about where that came from. It seems an unusual name for a community of practice.

Alacoque

Thanks, Olivia. Well, I suppose the story in brief is probably like many communities of practice, we didn't sit down one day and decide to form one. The group started when some like-minded colleagues within the Faculty of Business received funding to workon the enhancement of sustainability literacy among students. And we use the Sulitest, sustainability literacy platform[14]. Specifically, the Sulitest awareness quiz[15], as a stimulus to start the conversation around sustainability, and then build additional assignments around it to provide opportunities for students to deepen their knowledge and understanding. And we shared our reflections on this activity in various university wide forums and began to make connections with colleagues outside of business and to think about how we might be able to work together[16]. The initial group formed in 2020. And I'll never forget Olivia calling me and asking me if I'd like to be involved because it was at the end of the first lockdown.

12 Décamps et al. (2017) define sustainability literacy as the knowledge, skills and mindsets that help compel an individual to become deeply committed to building a sustainable future.

13 www.sdgliteracy.ie

14 www.Sulitest.org

15 The Sulitest is a multiple choice quiz. It's hosted on an online platform, which is supported by the UN. The quiz is designed to measure and improve people's awareness of the SDG framework, and the interconnectedness of the Sustainable Development Goals.

16 See Freeman et al. (2021) for a roundtable podcast published in Irish Journal of Academic Practice

And despite my exhaustion, I was delighted to connect with colleagues over sustainability education. Other meetings and presentations on our work happened on MS TEAMs and there was certainly an advantage with this as you have a captive audience and colleagues from across the university could attend as logistics wasn't an issue. I have to say for me, this was a big positive of community of practice: getting to work with amazing colleagues from across the university and having an opportunity to see their work in the sustainability space. We were successful in achieving additional funding to grow the team. And we quickly found ourselves in need of a website, which would serve as a virtual home for this growing group. We had a number of student members in our community of practice, and they brainstormed some names. And we voted for SDGLiteracy.ie, which is appropriate as our understanding of sustainability is encapsulated by the UN 17 SDGs. And we were very fortunate that we had Shaun Ferns on the team who could build the SDG Literacy website for us.

Olivia

Absolutely, yes. Okay. Thanks, Alacoque. So, so in terms of the timeline, the smaller group began working in September 2020, as you said, and then the larger group assembled in early '21. So perhaps I might turn to Patrice, now, to ask you, please, can you share how you became involved with the group, and how it has impacted your own professional practices?

Patrice

Sure, Olivia. Like Alacoque was saying, most meetings happened on Teams, and that's true. And that was the advantage for me, that most of those meetings were happening virtually throughout the COVID pandemic. Because if we were trying to meet in person, I'm not sure I would have attended as many meetings as I did. When I started attending the SDG Literacy, I was struck by the expertise of everybody at that meeting in different areas of sustainability across the different disciplines. So, I took guidance from you guys on the Sulitest and the reflective writing. I'm an environmental chemist and I got my chemistry students to take the Sulitest and to write that reflective writing piece afterwards. And really what I was finding was that my chemistry students were seeing sustainability as an environmental issue only and weren't seeing the bigger picture of sustainability. So, we had to do something about that. And actually, it was Alacoque's passion for sustainability and her knowledge of fast fashion and her expertise in supply chain management that made me think one day, do you know what; chemists have a big role to play in the fashion industry. Like, for example, there are 8000 synthetic chemicals used in the fashion manufacturing process[17]. Now, a lot of these chemicals, where do they end up? Unfortunately, they can make their way into the environment. And they're extremely toxic. We call them persistent organic pollutants and they're very slow to degrade in the environment and I teach my chemistry students a lot about that[18]. But by being able to bring in the fashion industry and Alacoque's expertise, we came together and actually, we ran a very successful seminar that coincided with World Water Day in March 2021[19]. And what we did was, we tried to raise awareness of the global water crisis and the role that we all have in achieving all of the SDGs. And my students got so much out of it. Like, for instance, it takes, about 7000 litres of water to make an average pair of jeans and that can support an African family

17 https://www.greenamerica.org/program/toxic-textiles [accessed 25 April 2022]

18 See van der Veen I., Hanning A-C., Stare A., Leonards P.E.G., de Boer J., Weiss J.M., 2020.

19 https://sdgliteracy.ie/2021/03/24/631/

for an entire year[20]. What they were able to see throughout this seminar, was the societal pillar of sustainability and how it did relate to them as scientists. So that was wonderful. And following that, the quality of the reflective writing pieces that were submitted by my students certainly improved. And another thing actually Olivia, I have a colleague here in the School of Chemical and Pharmaceutical Sciences who uses gamification as an active learning strategy. And that's Dr. Sarah Rawe. And she's very successful at this in first year science tutorials, to teach simple concepts of science. But what we did was that Dr. Sarah Rawe and Dr. Eoin McGillicuddy and I, we came together, and we designed an escape room for our students around sustainability literacy[21]. And actually, we designed it in such a way that it supports the UN's Sulitest. And what we have found from our students is that it enhanced their learning and definitely their engagement has increased. Their enthusiasm and their communication skills have all really improved by running this alongside the Sulitest, and then, asking them to write the reflective piece. So, we've come a long way in terms of sustainability in our school, and we're now sharing it out across the faculty of science. I can see changes happening, which is wonderful. And that's all thanks to our community of practice SDG Literacy.

Olivia
That's great, Patrice. I think the interconnections of the SDGs are so important. We know that they don't exist in isolation, they're all interconnected. And we can almost use that then to find opportunities for ourselves to interconnect.

Patrice
Yeah.

Olivia
...and to potentially grow the cross faculty work that is beginning to take place in this area.

Patrice
That's true Olivia, that's important that cross disciplinary nature of sustainability. We're starting to get to grips with it. And we have a lot more work to do and I believe we will get there. And I think this group is going to help us facilitate that for sure. But definitely, you're right the cross disciplinary nature of sustainability is so important.

Olivia
And really nice to sort of hear of your students recognizing that and, and I suppose maybe engaging in assessments that they might not have, styles of assessment that they might not have engaged in before, like the reflection. Now I know that yourself, Alacoque and Sheona have also developed an open education resource for SDG 1 'No Poverty'[22] and I am going to come to that in a minute. But if it's okay, I might first bring in Lucia. We've heard a little bit about assessment, Lucia, but do you think that the, that this community of practice has had an impact on assessment strategies around education for sustainable development? Can you talk us through a little bit about that?

20 https://www.rte.ie/brainstorm/2021/0319/1204928-water-save-conserve-value-ireland/[accessed 25 April 2022]

21 See Qureshi, S. M. Q. (2020) for a discussion of the importance of technology as an enabler to sustainable literacy

22 https://sdgliteracy.ie/goal1/

Lucia
Yeah, for sure. It's great to hear reflections of the colleagues on how beneficial they found this community of practice. It's the same for me and I have really gained not just knowledge and friends, but also confidence in venturing into more non-traditional assessments and linking them to sustainability. We found Sulitest to be a really excellent tool for contributing to enhancing of sustainability literacy but not as a standalone tool. Students often take MCQs but without pausing and reflecting, the awareness may be only superficial and then they just forget and move on to something next. So we incorporated three steps in connecting Sulitest to reflection[23], and then to authentic assessment[24] pieces. All of our students at Faculty of Business took Sulitest and they didn't get any grade because it was just about their own knowledge and skills. Then they reflected on their experience using the DIEP[25] framework, which was structured around describing, interpreting, evaluating, and planning. And we also provided some prompts to guide the students. The last part was linked to the authentic assessment piece, which was discipline and module specific.

Olivia
Ok.

Lucia
We all adjusted this approach also to suit our individual disciplines but also individual cohorts of students. We have had run these assessments with undergraduate, postgraduate but even executive learners, and some of these authentic assessments that we have developed, included: creation of short videos aimed at practitioners and shared on LinkedIn; podcasts; content development for Instagram with sustainability activists; student activism; development of e-portfolios using Wix; but also some of the other innovative ways like Patrice's escape room and other types of assessment. Just to give one example of what I have done - in one of my modules called International Management, the students completed Sulitest, then they reflected on it, and then they worked on a piece that was authentic assessment linked. This involved creating a video around one SDG issue that the students found of relevance, then they related it to a particular industry and in the last part of the video they made actionable recommendations for practitioners. For example, one student focused on gender equality in construction industry and made some really good call to action with recommendations that could be actually implemented. They shared the videos on LinkedIn, for many of them setting up LinkedIn profile was quite new, so again, they learnt something new there as well. And they created engagement and impact. I think some of those videos had over 2,000 views and lots of comments, which was really empowering for the students. This assignment I just spoke about was an integrated assignment with Supply Chain Management module that is led by Alacoque. The students didn't have to do Sulitest reflection again but instead, they created another authentic assessment piece that was linked to student activism. Alacoque, do you want to add more to this?

23 See Boud, Keogh & Walker (1985) and Closs & Antonello (2011)

24 The key principle of authentic assessment is that "authenticity" helps students understand the complexity of work, contextualise their own skills and allows students to develop new work ready skills & soft skills (such as reflection) (Mueller, 2005; Ashford-Rowe et al., 2014; Villarroel et al., 2018)

25 See Boud, Keogh & Walker (1985) for DIEP framework.

Alacoque
Yeah, so the student's kind of with, with their supply chain piece, they debated, who ... where responsibility in the supply chain lies with for sustainability.[26] And then having identified where they think responsibility lied, they were tasked with using their own voice, and to contact a policymaker, a TD, or even a brand. And I think using activism in assessment is quite a new concept. But the fact that global citizenship is being recognized as such an important skill for graduates, we hope that activism will be incorporated into authentic assessment strategies across the university. And that civic engagement and student activism will be supported within this community of practice.[27]

Olivia
So Shaun, perhaps you could tell us a little bit about how this community of practice has shaped approaches to education for sustainable development across the university? Like what, what are your thoughts on I suppose the wider impact of some of the work that we've heard Patrice and Lucia and Alacoque discuss?

Shaun
Brilliant, Olivia, and thanks for this. I suppose when Cormac aligned the work of the community of practice to the strategic intent of the university. And we see sustainability and practices being, I suppose, one of the three pillars of the university. As we speak now the university is developing its education model[28], and probably central to that is putting ownership for the learning and the teaching in the student's hand and allowing them to take responsibility but also seeing the university as a larger kind of learning community. We're engaged with the wider community as part of that learning. We see that straight through with the SDGs around the quality or "Number 4 Quality Education," and the part that plays so the building of the community of practice in particular around sustainability and SDG literacy kind of helps the university fulfill its roles and its obligations under the strategic plan. But I think it helps inform and engage with the wider community. And it brings that wider community into the university. So both parts of that community grow because of that interaction and collaboration.

Olivia
Okay, very good, very interesting Shaun, thanks. Lucia did you want to come in there...on that one?

Lucia
Yeah, like, Cormac and Shaun mentioned, we see ourselves as grassroots activists of community of practice, and really growing, we also see students are looking for more on this. And before we get there, with regards to having sustainability as part of all programs, and all of the modules and everything that we do, we have been engaging in these interesting activities in the meantime, and it is supported by the university strategy, we now also have a VP for Sustainability, we have been engaging with them. And we see our collaboration is growing as sustainability becomes more embedded, as I said earlier. Some of us are also

26 See Boström, Magnus, et al. (2015).

27 See Killick,(2013)

28 TU Dublin (2021) Education Model Philosophy

part of the Green Campus Committee so we are strengthening those connections. We are also engaging with students societies like Enactus[29], which runs really interesting social innovation projects and there is also an emerging student led sustainability society. All these activities are happening across the whole of university, and across different stakeholder groups and disciplines.

Olivia

Yeah, and I can see the way as we're discussing it, it's, it's, I mean, the Sulitest itself is all about awareness. But all of this activity is really contributing to an expansion of awareness for staff, as well as students across the university context. So I'm going to turn now to Odette. So, Odette, you're coming to education for sustainable development. From a languages perspective, you're probably closer to ideas about global citizenship[30] and cross-cultural experiences than many of our colleagues. And you were the first member of the community of practice to utilize the software package 'Articulate' to create an online lesson. So, I'm interested to hear about that. And to hear about how being involved in this community of practice has impacted your work.

Odette

Okay, thanks, Olivia. So when I first heard from you and from Cormac that you were setting up a sustainable literacy CoP, I was really delighted to be able to join it. Because I've had an interest in environmental issues since I was a teenager. When back in the 80s, I was one of these activists that supported Greenpeace! So I was quite aware of Agenda 2030, but I hadn't really kept up to date with the United Nations detailed work around the SDGs. So the CoP made me realize the enormous potential of integrating SDGs in our language learning curricula. And in my case, I'm lucky to teach a year four optional French module, which is called Current Affairs in France and Francophone countries. And it's actually ideal for embedding SDGs. In fact, most if not all, current affairs issues can be connected to one SDG or another. So this year, I've systematically used the SDGs as a lens to consider our French and Francophone current affairs topics in a critical and systematic way, through all our class activities, group discussions, debates, and the assessments as well. Maybe another impact that the CoP has had on my work, and that of a colleague, in Spanish, Pilar Molina, is that we propose to edit a special issue on sustainability literacy in language learning and teaching for a journal on language learning in higher education. And we would never have come up with this idea if we have not been part of the community of practice.

Olivia

Okay, that's really, really good to hear. And I suppose it makes me think of the fact that the community of practice, it takes time out because you have to take time out to turn up and

29 Enactus (https://enactus.org/) is the world's largest student-led and student-focused experiential learning initiative which connects 35 countries, 1,8000 university programmes, over 72,000 students and 550 corporate partners. It is directly connected with addressing the UN SDGs through social innovation pursued by students-social entrepreneurs, future leaders.

30 Lilley et al. (2017a, p.6) cite a UNESCO (2015) report which identified the need for forms of education that enable learners to address local and global challenges, as socially responsible, critical and ethical thinking graduates, a disposition consistent with the global citizen. See McAvinia et al. (2021) for further discussion of this in the context of TU Dublin.

be present. But it also provides us with headspace, doesn't it? To think about, you know, kind of new and innovative things we could be doing and to make those connections, probably a connection that you already had, but then to think about something new to do together.

Odette
And very much discover new aspects to it and you know, further explore what you might be able to do with this. Yes, absolutely.

Olivia
Yeah, fantastic. And I know that you've used Sulitest with your language students, I think you used the French version of Sulitest if I'm not wrong. Can you tell us a bit about that?

Odette
Yeah, that's right. I use the French version, because as you know, there are regional versions available for the Sulitest. This means that these regional versions include questions that are relevant to the local context, and that are in the target language. So in my case, I asked our year three students who are doing French to take the Sulitest French version. So the questions are in French, and a number of the questions are of relevance to France or to Francophone countries. And I know my colleague in Spanish, Pilar Molina, again does the equivalent with her students of Spanish. And we use it as a reading comprehension exercise. And then I use it as well as a springboard for another language task that's based on SDG 11: Sustainable Cities and Communities.

Olivia
Fantastic, that's really great, Odette. So it's always interesting to hear how people are, you know, utilizing the various tools in different ways. You've also worked on producing an OER[31] on SDG 12 isn't it?

Odette
Yeah. Yeah, I did. I always really enjoyed developing OERs for French language learning. So I kind of jump on any opportunity to do that. And this was really a good opportunity to bring together language learning and SDGs and develop a resource and make it widely available. I decided to design this in such a way that it would be not only useful for an autonomous language learner, but also to provide my colleagues teaching French, both within TU Dublin and beyond with a resource that they could adapt for their own classes. I know some of my colleagues have used the resource this year, particularly in year two. It's based on SDG 12, which is about responsible consumption and production. I thought when I was designing it, that it might be nice to have two different lesson plans for it. One lesson is on responsible consumption. And it shows how a family changed their food consumption habits. And the other lesson is on responsible production, and that one focuses on the French car manufacturer Renault, and their innovative sustainable processes in manufacturing cars. And each lesson is pitched at a different language competency level. Also, as it happened, one of my final year students last year did a really good presentation on SDG 12 and food consumption. So I included her presentation with

31 UNESCO Commonwealth of Learning (2011 and 2015).

her voice over as part of the lesson. Because I thought it was nice to have one of our students featured in the OER. And as well as that it's a good way of including the student voice and showing a good example for what our current students can aspire to do with their French and SDGs.

Olivia
Thank you, thank you so much I think on behalf of the Community of Practice for doing this because we as a group had discussed different software options and wanted to develop these online lessons. And you grabbed the bull by the horns and did it and I think that inspired Sheona and Alacoque and Patrice as well to develop their one. So Sheona tell us about the OER that you've been working on. And first of all, tell us how you got involved in the group.

Sheona
Thanks, Olivia. So yes, I've been working in the School of Culinary Arts[32] since 2015 and started to develop some dedicated food-focused sustainability modules for a couple of our programs. I was probably first introduced to Sulitest by Andy Maguire, who was our Sustainability Coordinator at the time, and I thought it was a great resource, so I started to use it. The way I used it was: I tested students at the beginning of the module and at the end of the module, to see if they made any kind of progress. I asked them to reflect on whether they recognised, their own gaps, and whether they then felt that they had filled those gaps over the course of the module[33]. But our school is quite small and I suppose our student numbers are much lower than say, for example, in Business. So, when I heard the Faculty of Business had started using Sulitest in 2020, I thought this was great. The idea of forming a Community of Practice: I found that really exciting. So, I suppose, I felt this CoP would be able to provide the potential to scale up the use of Sulitest, and would also provide the opportunity for me and others to collaborate. So, you know, it gave us the ability to work together from different disciplines. And it was really useful in developing ideas around teaching, learning and assessment methods. Also, as you know, we haven't mentioned it yet, but we are trying to develop a regional Sulitest module, focused on Ireland. I think that it would be really useful if we could integrate that. But one of the offshoots, which you've asked me about, is the CoP on SDG 1. So as part of the larger CoP, we've kind of subdivided into clusters based on the SDGs that we each had an interest in. So, myself, Alacoque, and Patrice came together for SDG 1, 2, and 6. And I think because there was only three of us, and I think also, because as Patrice has earlier mentioned, we can do this virtually so easily on MSTeams, we were able to meet quite easily. We got together and got the ball rolling. And I think we all enjoyed it, we worked well together. My own personal interest in poverty stems back to earlier even before I was in education when I originally studied Development Economics, and what I really wanted to achieve with the OER for SDG 1[34] was to try and show the students the multi-dimensional aspects of poverty, and how Ireland even though we're a so-called developed country, you know, that we suffer from poverty as well, and how all this is linked

32 https://www.tudublin.ie/explore/schools-and-disciplines/culinary-hospitality- tourism/culinary-arts-food-technology/

33 See Brekken CA, Peterson HH, King RP, Conner D. (2018)

34 https://sdgs.un.org/goals/goal1

to sustainable development and the economic models that our societies are based upon. Also, to try and demonstrate that food is very much a part of that space, and that sustainability can be seen, I suppose, you could argue as a Nexus issue that brings a lot of these issues together. But what really enabled our cluster to get the OER over the line was the help of another colleague, who's here today as well, Shaun Ferns. He transposed our work onto the platform Articulate Rise 360[35]. So that is where it is now. And I suppose we see it, as you know, as a trigger for other groups to develop more OERs, as you've mentioned.[36]

Olivia
Great, thanks. Thanks so much for all of that Sheona. Yes, I agree. We have been so lucky to have Shaun, our technology guru. And technology has been an enabling factor for this community of practice, for sure, in so many different ways. And I'm not sure that we would have really been able to, to sort of flourish at all without the various technological enablers that we've used. So Shaun, you might talk a little bit more about that, and kind of the importance of technology for CoPs.

Shaun
Thanks, Olivia. And we've heard a lot of technology described, I suppose through the presentation. So far, and much of the work we do is entangled with technology[37] of various sorts, in particular, this community of practice, digital technology, seemed to play a central role. One of the first things we identified for the community of practice was a home. So if we have a community, we need a base or a home to work from, and a place to connect the large amount of work we were doing individually and collectively that was being developed. And in terms of sustainability. So in addition, and most importantly, we needed a place to share and celebrate the work. And I think when we build communities, we need to be sharing what we're doing on a continual basis, but we need to use that as a way to celebrate and celebration that and excuse the pun sustains the life, the community. So the development of the website was a key goal. And the site ended up becoming a one stop shop for the community, and it includes all the links of social media, links to the Sulitest. And for me, some of the most exciting elements is a place to host the newly developed OERs in relation to the seventeen goals. So as part of the community practice, and through our use of technology, we've seen this as an opportunity to be open and transparent with our practice, as well as to make visible so that we can all play a part of shaping that future educational, sustainable practice[38]. And as part of the project of the work of the community, you'll have heard about the development of particular OERs through Articulate Rise. And I suppose as a group, we see them as the key educational components of the community of practice or one part of that. And I suppose from a developmental point of view, it's been great to see staff engage with the technology, develop and improve their digital skills, and then share these newfound skills not only with the rest of the community, but then their learners. And you can see that through the development of learning portfolios, they're

35 https://articulate.com/360/rise

36 See our OER on SDG 1 https://sdgliteracy.ie/goal1/

37 Fawns, (2021)

38 Krznaric (2020) - The Good Ancestor reveals six profound ways in which we can all learn to think long-term, exploring how we can reawaken often neglected but uniquely human talents like 'cathedral thinking' that expand our time horizons and sharpen our foresight.

building websites on Wix or their videos they shared on LinkedIn. The whole community, both staff and students have risen together with their digital skills. And then lastly, all of the OERs developed by the community, find a long term sustainable home in TOTAL[39] which is TU Dublin's institutional OER repository. And that forms part of the Arrow[40] institutional repository. So we can see, technology has been an enabler of the community of practice, but it's the community and digital plays one part of that.

Olivia
Yeah, absolutely. Alacoque did you want to add anything around that I suppose Shaun mentioned about, you know, some of the technologies that students are utilising as well, students might not be direct members of the community of practice. But, you know, staff that are part of this community of practice are bringing students in and trying to engage with technology and trying to help them be able to share their learning on a wider scale.

Alacoque
Yeah, we've used digital technology, it's been an enabler in designing our assessments, we've used our own VLE Brightspace, as well as the UN Sulitest platform. And we've also directed our students to the All Aboard higher education platform[41] to encourage them to develop their digital skills such as video making. And Lucia and I, for our fourth year modules, we got our students to create different artifacts, digital artifacts, and collate them in one e-portfolio, which they built using Wix.[42]And this allowed integration of knowledge and enabled the students to see connections across our modules. And the e-portfolio showcases their learning throughout the programme. And it contributes to building their professional identity online.[43]And students have reported that they're using those e-portfolios when applying for jobs.

Olivia
So it's a way to reach outside of the university, which is becoming increasingly important. And I know we have quite a strong social media presence as well, largely thanks to Cormac who does a great job in keeping Twitter in particular updated. What do any of you think about the importance of social media for the community of practice? As this group continues to expand?

Shaun
Thanks for that, Olivia. I'll jump in there, if you don't mind.

Olivia
Thanks.

39 TOTAL, (2022) https://arrow.tudublin.ie/totaloers/

40 https://arrow.tudublin.ie/

41 https://www.allaboardhe.ie/

42 https://www.wix.com/

43 See Amaya et al. (2013)

Shaun
That idea of we talk and discuss what a community looks like and then what it feels like. And communities are about a level playing field for all the members of the community and social media has allowed us to communicate both the purpose, the goals, and keep each other up to date, and it's that interaction, through announcements on like, you've used the example of Twitter, sharing the work we do on Instagram or LinkedIn, that it's that interconnection of relationships, I think Foucault[44] says we all live in relationships and the interrelationship and the workings of that that makes us a strong community. And without that continual thread that Cormac has, so professionally kind of delivered through the social media. For me, that's what pulls us together and makes us unique.

Olivia
Okay, yeah. And I think it's been, you know, I suppose one of the activities of our community of practice has been around, you know, presenting some of what we're doing at conferences and inviting guests in. And I think social media really comes into its own then too, because it's a way that we can continue ongoing conversations with guests and, you know, really kind of hold on to those connections. So it's very meaningful activity, I think, and a time consuming activity. I think we're all grateful certainly to Cormac that he keeps on top of it, but it's, it's, worth it for concretizing some of those links. Okay, so another area, I suppose that I thought it would be useful for us to discuss is the area of professional development and academic literature on communities of practice suggests that CoPs can be a catalyst to encourage otherwise time constrained staff with professional development opportunities. And I think some of that has kind of come out in the discussions we've had so far. But I know Cormac and Lucia have been involved in the development of a new CPD around sustainability education. So I might turn to Lucia, are you seeing synergies between the activities of the CoP and engagement by academic staff with formal professional development?

Lucia
Yeah, for sure. We were part of a project, myself and Cormac, funded by the National Teaching and Learning Forum called "Impact." And we worked with colleagues from different disciplines from food science, pharma & biopharma, tourism & hospitality, management and business. Together, we developed a certificate - a CPD (certificate professional development) in education for sustainability, based on a pilot that ran in food science previously, and then we adapted parts of it to different disciplines. Cormac has been delivering this, and it has been really successful and impactful, because when colleagues take the program, they don't just gain the knowledge and skills, but they also gain other competencies, connections and confidence. And then they're able to embed it into their own teaching practice. We also created a Level 8[45] discipline specific modules for students and delivered them to final year undergraduate students. For example, I have delivered the business sustainability version as an option to final year business students. It was a new offering last September. I expected maybe 30 students, but we ended up with 94 of them. This really shows that there's a great interest by our students in this area. This groundwork

44 See Gilbert (1999)

45 The Irish National Framework of Qualifications (QQI) Level 8 is an equivalent of a Bachelors Degree https://www.qqi.ie/what-we-do/the-qualifications-system/national- framework-of-qualifications

led to audit of programmes and programme development. I'm a programme chair of Postgraduate Certificate in Business Sustainability Leadership and developed this programme with other SDG Literacy CoP colleagues, mainly Olivia and Alacoque. We all teach on this program as well. One really impactful element of this program is a consultancy project. Students who are working are addressing a real business sustainability issue. Apart from producing a roadmap of actions for their organizations, they are also develop pitching skills. When the consultancy project is finished, they're ready to go and involve different stakeholders and created a buy-in and real impact. We also opened up some of these guest talks and other events to others in the community of practice and other colleagues and postgraduate students. You can see how something that starts really small grows and grows and the impact grows as well with it, which is great.

Olivia
Absolutely. Thanks, thanks for shedding some light on all of that Lucia. So as we come to a close now, I thought it might be useful to reflect on one of the difficulties of any community of practice, and that is sustaining engagement, and also endeavoring to create a feeling of mutual gain. So I suppose I feel that the brand identity that we've talked about SDGLiteracy.ie, the website, the social media presence, certainly has helped to build and sustain a sense of togetherness. I suppose I've been thinking about it. And if we were to visualize our CoP, it might be concentric circles as sort of a core group at the beginning at the middle of it all, who are actively engaged and continually, continuously innovating, an inner circle who are spreading the word on our shared passions and practices and their own teaching and learning contexts. And engaging in CPD in this area. And then maybe an outer circle who are dipping in and out and becoming more familiar with approaches to sustainability education, without fully committing to them just yet. And I think there's fluidity between these groups, it's probably fairly typical of community of practice that it might look something like this. So before we close, I wanted to ask all of you, what are your biggest takeaways from your involvement as members of the core group? And what ideas do you have around? That? That sustenance piece? I suppose it's a question about challenges and opportunities. How do we keep the community going? How, and most importantly, how do we keep education for sustainability top of the agenda? So who would like to go first jump in to answer this big question.

Patrice
Olivia, I really think we're very lucky here in TU Dublin that our university's strategic intent[46] is built around the three pillars of sustainability. And we here in TU Dublin, call it people, planet, partnership, but it's built around sustainability. So we're very lucky that we have that high level support for sustainability. And I think that is going to help us to keep our community of practice alive and to keep sustainability on the agenda.

Olivia
Yes, I agree with you that that strategic umbrella is so important to what we're doing. Alacoque did you want to come in?

46 https://www.tudublin.ie/explore/about-the-university/strategicintent/2030/

Alacoque
I agree with Patrice that having that support from above is so crucial. And I can see now from my students in supply chain management, they're telling me that, you know, employers are looking for sustainability in their CV. And looking for them to have a sustainable supply chain module. So we're developing those at undergraduate and, and at level nine. And being part of this community of practice, you know, we've been able to organize events for students that have been really impactful for them. Like the sustainable fashion event, last October,[47] where we had an ex-garment worker speak to the students, and I think support for those kinds of events and support for continuing building our OERs or other micro credentials is crucial.

Olivia
Thank you. Thanks Alacoque. Odette?

Odette
Yeah, I'm just thinking that perhaps maybe another way of leveraging the opportunities that are provided by the CoP is to encourage the creation of multidisciplinary projects and collaborations between students, students of different disciplines, a bit like what maybe Patrice described earlier in the discussion when she mentioned that her chemistry students saw the relevance of SDGs when she worked together with Alacoque on the fashion industry, and maybe if that, you know, if we're getting students from different disciplines and different programs, to work together on a project or an assessment, and bringing different SDGs together, depending on their own discipline, that it could really open up new opportunities for both sustainability in TU Dublin and for a multidisciplinary project as well as for the community of practice, because it will be an enabler of all of that.

Olivia
Yeah, yeah. And I think, as the Community of Practice grows, the opportunities for finding the right people to talk to be able to do something like that, you know, that the opportunity is growing as well. And I think a lot of people are, you know, interested in, you know, breaking down the silos between disciplines[48], and looking for those opportunities to do something different and really meaningful. I think both staff and students are interested in that. So yeah, absolutely agree. Shaun, what are your thoughts?

Shaun
Yeah, thanks, Olivia. I was struck by your comments around that the idea of what a community and the concentric circles and those who are central or core and those on the external. And I'm also thinking about sustainability in terms of our individual and collective responsibilities to meet the sustainable goals. And sometimes we describe collaborations as mutually beneficial, well-defined relationships entered into by two or more groups, to achieve common goals. And I think we're moving past that kind of definition of collaboration[49]. And we're really moving into this space of community. And community is about that

47 See https://www.youtube.com/watch?app=desktop&v=FdBJfKthmFM for recording of this event

48 See Freeman, Hand, Kennedy (2021)

49 See Ferguson et al (2019)

collective responsibility about achieving our sustainable goals, and not just looking about what the individual effect of our actions are. And I think if we're going to meet our targets around sustainability, it'll be our collective effort, and our collective responsibility will become clear. And, like, I'm really fortunate enough to be part of this community of practice. And that what keeps drawing me back is a sense of community by all of the participants engaging in any way they can. And that's why I'm quite proud to be part of the SDG literacy group.

Olivia
Great, thanks, Shaun. Odette?

Odette
Yeah, I also think that, for instance, I have participated in the CoP, I've done the CPD module on sustainability. And, you know, I'm getting more comfortable with the idea of embedding the SDGs into one of my modules, but I find that engaging with other colleagues on the topic really helps me to develop and refine the teaching and learning methods that I can use to nurture the competencies that are integral to education for sustainable development[50]. And I'm thinking of competencies that are quite complex to nurture such as systemic thinking, collaborative working, values thinking, and they're all really relevant to building a sustainable future, and they're the ones that will enable us all, to quote a French philosopher, Latour[51], he talks about landing back to Earth and getting connected to our local context. He's doing a lot of work on the Anthropocene, and trying to engage communities into what we can do to be enablers of change in terms of sustainability.

Olivia
Yeah, excellent. And it's back to that global citizenship piece as well isn't, as you know, trying to, for us all to come to grips with what exactly does that mean? Because I don't think it's, you know, is about sort of doing an Erasmus program or, you know, going, going somewhere for three months, that's part of it, but it's about understanding how global citizenship can be nurtured and achieved, actually, in local contexts. And through having, you know, nurturing in our students, you know, a full understanding of, of the task ahead of us in terms of sustainability,

Odette
Yeah and understanding these interdependencies. And like, moving from a top-down approach, you know, from the French perspective, it's very much a Cartesian approach where, it's top down, with the dominant ideology of the economic systems, and instead, getting a ground up change and approach

Olivia
Bottom up...

50 See Wiek, A., Withycombe, L. & Redman, C.L. (2011).

51 See Latour, B. (2021). Où suis-je ? Leçons du confinement à l'usage des terrestres. Editions La Découverte

Odette
…that’s it, bottom up approach.

Olivia
Yeah. Thanks, Odette.

Odette
And that’s where the community of practice can be very effective.

Olivia
Yeah. And it feels like a very grassroots experience, I think, certainly for me, as well. And Lucia, Sheona, do you have anything you’d like to add, before we come to a close?

Sheona
I’d agree with everything that everybody has said there. I think what is really empowering is to be able to work across disciplines and just to see other disciplines’ take on “sustainability”. Trying to look at sustainability just from a food perspective is too narrow. I think also it empowers my teaching, I think just by being involved and seeing the other aspects or the others’ take on it.

Lucia
Yeah, I think, as Shaun said earlier, it’s not our own individual actions, but it’s the collective actions of us as a community, not just us but our students and everyone else who gets involved with these initiatives. I think together we should be very proud of our achievements to date because we have done so much in so many different ways and using such innovative ways of thinking and engaging with students. One thing that we need to think about going forward is how we’re going to manage this community of practice so that it continues to thrive and grow and make impact. How can we get supported in terms of, us as a rotating committee or where we can get funding too for some of us to take time out to really coordinate and focus on these activities?

Olivia
Yes, well said Lucia. Okay, well, I think we have come to a close now. I’d like to thank everybody for joining me today and for sharing your experiences and insights. And I’d like to thank anybody listening to this podcast. And if you would like to find out more about our community of practice, please do visit our website SDGLiteracy.ie. And thank you very much for your interest.

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EFFECTIVE LEARNING WITH FUN: OPENARTBROWSER

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ABSTRACT

Project-based learning is effective, particularly if it is fun for everybody involved. openArtBrowser is a web app for learning about creative arts, developed as part of a student project. This paper discusses success factors for project-based learning from the openArtBrowser experience.

Keywords: Project-based learning, software engineering, web app, creative arts.

1 INTRODUCTION

Project-based learning [1] is an effective way of learning, particularly when if it is fun for everybody involved. In this paper, the student project openArtBrowser is introduced, in which more than 30 B.Sc. and M.Sc. students developed a web app over 7 semesters. In this course, students developed professional software engineering skills but at the same time had fun developing something meaningful. The web app itself also supports learning with fun, in the domain of creative arts.

The paper is structure as follows. Section 2 introduces the web app. Section 3 describes aspects of the student project, including team organization, release planning, quality management and knowledge management. In Section 4, learnings from the project are discussed. Section 5 concludes the paper and indicates future work.

2 OPENARTBROWSER

2.1 WEB APP

openArtBrowser[1] is a web app which invites users to browse through the world of creative arts, enjoy beautiful artworks and learn interesting things. Targeted users range from people without knowledge about creative arts, over amateur art enthusiasts, up to art historians.

One key concept of openArtBrowser is serendipity, supporting finding without actively searching. The metaphor we use is "strolling through the virtual museum" and en passent discovering interesting things.

Fig. 1 shows the start page of openArtBrowser. It is animated and displays varying examples for artworks, artists, movements, artwork types, locations, material, genres and motifs. By clicking on a topic, a respective page is opened. In addition, important artistic movements are displayed in form of a timeline, again with varying sample artworks.

1 https://openartbrowser.org

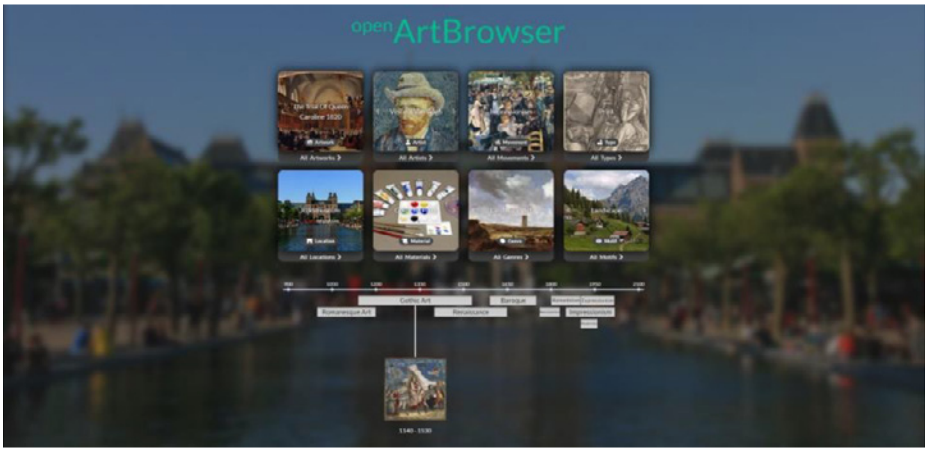

Fig. 1. openArtBrowser start page

When selecting an artwork, e.g., Mona Lisa, a detail page is being opened (see Fig. 2). The detail page displays a high-resolution image of the artwork which can be zoomed, together with its title and the artist. If the user is interested, comprehensive additional information is displayed, including a description, information about genre, movement, material, motifs, iconography, dimensions, provenance, and adequate videos.

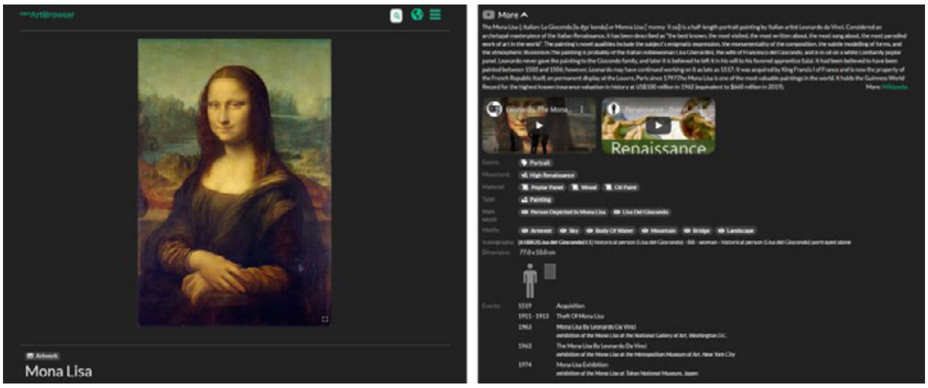

Fig. 2. Artwork detail page: example Mona Lisa

At the bottom of the detail page, related artworks are being shown. Relatedness may have various dimensions: the same main motif, artist, genre, location, material or movement. When hovering over one artwork, e.g., the "La belle ferronière", common tags with Mona Lisa are highlighted, e.g., both are portraits and oil paintings by Leonardo da Vinci. See Fig. 3.

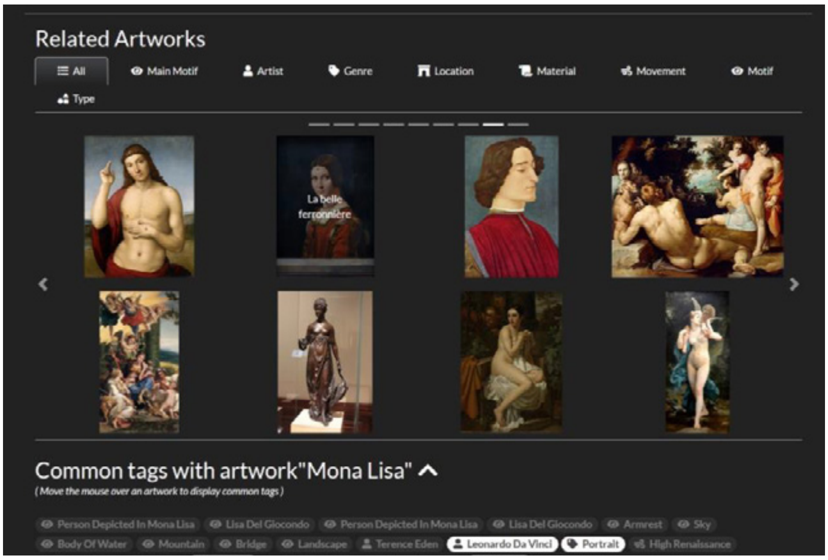

Fig. 3. Related artworks page, example Mona Lisa

In a similar manner, detail pages inform about artists, movements, genres etc., show multimedia background information, timelines, and corresponding artworks.

While serendipity is an important feature of openArtBrowser, active semantic search is also possible. Fig. 4 shows an example.

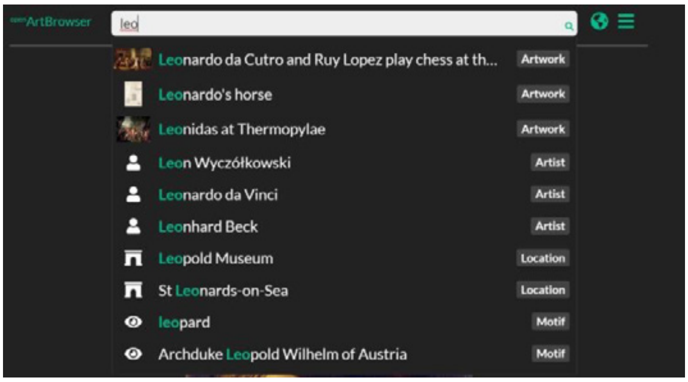

Fig. 4. Semantic search

While typing “leo...” in the search bar, matching entities are automatically suggested. Entities could be artworks, like “Leonidas at Thermopylae”, artists like Leonardo da Vinci, Locations like the Leopold Museum, motifs like leopard, etc. Various advanced search options like full-text search or combinations of search terms are possible, too.

openArtBrowser is multi-lingual, offering English, German, French, Italian and Spanish. Due to its responsive design it can be accessed in web browsers on PCs as well as on smartphones and tablet computers. openArtBrowser is well-received by the Internet community. In 2021, users accessed the openArtBrowser 16,000 times, with 48,000 page views. They came from 82 countries, headed by the US, France, Germany, Italy and Spain.

To summarize, openArtBrowser allows effective learning about creative arts with fun.

2.2 DATA SOURCE

openArtBrowser is entirely based on open data. All pictures and metadata are open source from the Wikimedia foundation[2], and in particular from Wikidata[3]. Wikidata is a free knowledge base with about 100,000,000 data items that anyone can edit. Wikidata is the information backbone of openArtBrowser. All data items displayed in openArtBrowser are extracted weekly from Wikidata and prepared for usage in openArtBrowser. For technical details see [1].

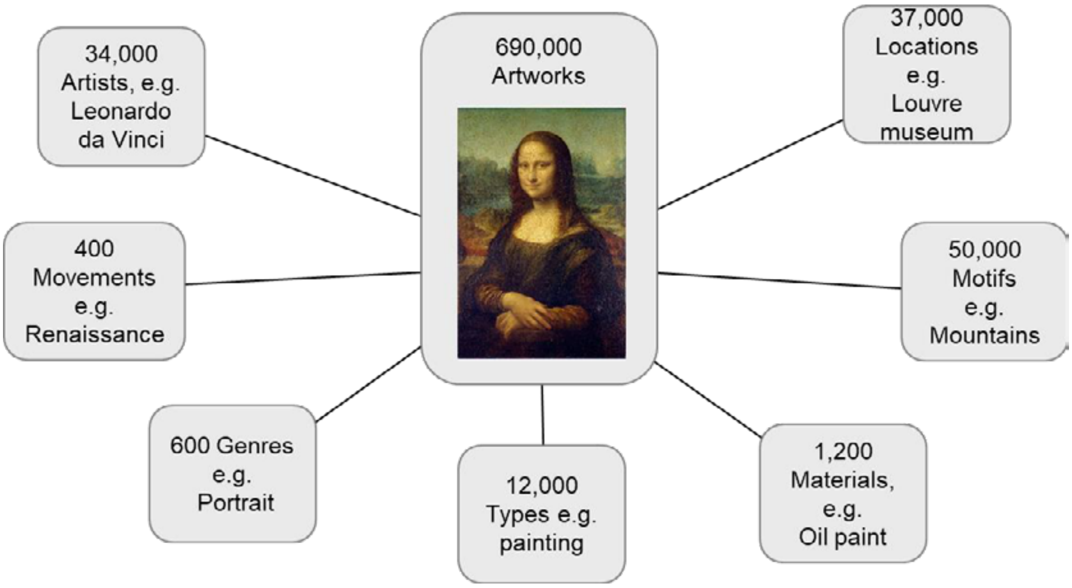

Fig. 5. Information model of openArtBrowser

Fig. 5 shows the information model of openArtBrowser. Artworks like Mona Lisa are central, in total currently 690,000. Associated with artworks are 34,000 artists like Leonardo da Vinci, 400 movements like Renaissance, 600 genres like portrait, 12,000 types like painting, 1,200 materials like oil paint, 50,000 motifs like mountains, and 37,000 locations like the Louvre museum. As data is retrieved from Wikidata regularly, the volume of openArtBrowser is increasing automatically, as users of Wikidata enter new artwork data.

2.3 RELATED PROJECTS

Digital Collection Städel Museum Frankfurt

openArtBrowser was inspired by the digital collection[4] of Städel Museum Frankfurt, Germany, which was originally developed as part of a large state-funded research project of the author [3, 4, 5, 6]. In this project, intense research and collaboration with the educational department of Städel Museum lead to the concepts of serendipity and its implementation in the creative arts context. In 2014, the author received the Hessian Research

2 https://www.wikimedia.org

3 https://www.wikidata.org

4 https://sammlung.staedelmuseum.de/en

Award of Universities of Applied Sciences for the research project, and in 2015 the “World Summit Award” in the category “Culture & Tourism” was awarded for the digital collection of Städel Museum.

While the data in this project was proprietary and restricted to the artworks of the Städel Museum, the idea was born to implement those concepts in an open source way, entirely based on open data. This idea lead to the openArtBrowswer project which is described in Section 3.

DDK Art Browser

openArtBrowser spawned interest in the art history community and so the author was contacted by members of the German Documentation Centre for Art History – Marburg Photo Archive (DDK Deutsches Dokumentationszentrum für Kunstgeschichte - Bildarchiv Foto Marburg[5]). With about two million original photographs, the institute, part of the University of Marburg, is one of the largest picture archives worldwide for European art and architecture. As part of the openArtBrowser project, a version of the web app particularly suited for DDK data has been developed in 2021.

3 STUDENT PROJECT

3.1 HISTORY

While the digital collection of Städel Museum was developed as part of a large, state-funded research project, openArtBrowser was entirely developed in study modules at the computer science department of Hochschule Darmstadt – University of Applied Sciences, without any funding.

In 2018, the first release of openArtBrowser was developed by an international B.Sc. student team with team members from Germany, United States, Morocco, Uzbekistan, Vietnam, and Indonesia. In the following six semesters, over 30 B.Sc. and M.Sc. students further developed the platform with great enthusiasm.

3.2 PROFESSIONAL SOFTWARE ENGINEERING

openArtBrowser is open source under the leading open source platform GitHub[6]. The student projects are run according to professional software engineering standards for open source projects. This includes the following aspects:

1. **Teams and roles:** Student teams are formed according to the tasks to be developed, e.g., app layout, web development, data extraction, data preparation and storage, etc. Specified project roles are assigned, e.g., business architect, technical architect, infrastructure manager, knowledge manager.
2. **Meeting structure:** Weekly team meetings allow synchronizing team members, clari-

5 https://www.uni-marburg.de/de/fotomarburg

6 https://github.com/hochschule-darmstadt/openartbrowser

fying issues and working out concepts. During the Corona pandemic, team meetings were performed using a video conferencing platform. In addition, electronic communication channels like instant messaging are used intensely. During the semester, feedback is exchanged between all students and professors. At the end of each semester, positive aspects and ideas for improvement are discussed in form of a retrospective. A social event including lunch concludes each semester project.
3. **Release planning:** Every semester, two releases of openArtBrowser are planned, with specified features and deadlines.
4. Development processes: Standardized and documented development processes are used, e.g., for issue management, source code management including branching and merging strategies etc.
5. **Quality management:** Every piece of code and documentation is rigorously reviewed in various stages before being put into production. In particular, all development code branches are reviewed by technical architects.
6. **Infrastructure:** Three development stages have been set up: (a) local development for features, (b) a staging server for integration testing, and (c) a production server for the web app. All stages are separated from each other in order to ensure stable production of openArtBrowser.
7. **Documentation:** The Wiki of the GitHub repository[7] contains comprehensive documentation including requirements, system architecture, installation guide and developer guide.
8. **Knowledge management:** openArtBrowser is a complex web app using many state-of-the-art technologies like, e.g., Angular, TypeScript, ElasticSearch, Python and numerous frameworks and libraries. Proficiency in those technologies and the openArtBrowser software architecture is challenging. Therefore, weekly short presentations on technical topics are an important aspect of knowledge management in the project.

4 DISCUSSION

As became clear from numerous student feedbacks and retrospectives, the students were enthusiastic about the project and learned a lot in the course. From the experience of the author, the following aspects are key to success:
1. **Meaningful product:** For students it is most motivating to develop something meaningful and useful. For openArtBrowser as a web app which can be shown to friends and which is used throughout the world, this is the case. In addition, educating about creative arts in a fun way is meaningful to our society.
2. **Sound basis:** Key to the success of openArtBrowser was the sound research and development work that preceded the project: the digital collection of Städel Museum. A lot of conceptual work on the educational aspects, user experience but also technology was already there to be built upon.

3. **Novelty:** The research aspect of openArtBrowser is interesting to students, developing something novel which did not exist before.

7 https://github.com/hochschule-darmstadt/openartbrowser/wiki

4. **Professionalism:** Professional software engineering skills are the main learning target of the project modules as part of the B.Sc. and M.Sc. studies at the computer science department of Hochschule Darmstadt – University of Applied sciences. Therefore, it is of upmost important, that this professionalism is rigorously conducted in the project.
5. **Fun:** Project work should also be fun in order to be effective. So, it is important to keep up a good mood by social events, but more importantly during the daily work. The feedback from students was consistently that the team atmosphere in openArtBrowser was great.

Project-based learning is most effective and having fun increases this effect.

5 CONCLUSION AND FUTURE WORK

In this article we presented openArtBrowser, a web app which allows users to learn about creative arts in a fun way. However, the student project in which openArtBrowser was developed, was also fun and, at the same time, a most effective learning experience in terms of professional software engineering.

Continuous improvement is part of good project practice, but also of good teaching practice. Therefore, we will continue developing innovative, meaningful apps like openArtBrowser with students in order to benefit society and best educate our students.

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BASICS OF MATHEMATICS VIA ROBOTICS

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ABSTRACT

Practicing and project-based learning are usually the luxury of the second and the third years students, because the classes get smaller and the basics are learned. The first year students, who come to high-school hoping to solve real problems, find themselves in the same theoretical world with pseudo realistic problems that they were bored by in the school. In this paper we discuss whether it is possible to start project-based learning directly at the beginning of a high-school in such a theoretical subject as mathematics.

Keywords: Practice-based learning · Transition to high-school.

1 MOTIVATION

Could you imagine a music lesson with a teacher who explains week after week the importance of the music notation, and how to read and write it, but never lets you play music? I am afraid that this is how the classes of mathematics look like for an engineer. In best case we solve toy-problems which are similar to later application. However solving problems on paper are never as persuading as seeing things working. Professors who ask, why students can't feel the beauty of mathematics, may again compare it to music. An experienced musician will get enlightened by reading a beautiful music sheet, but not a beginner. Beginner has to hear the music first.

But a beginner can't play a complicated tune. So what can we do with first year students? Modern music courses use play-black and let the student add his simple tune to a whole piece. In this paper I show which kind of "Playback" I developed for students of mechanical engineering and why robotic projects were useful to deepen their understanding of very basic mathematical notions.

2 MATHEMATICS TROUGH ROBOTICS

There exist several excellent projects for teaching mathematics through programming and robotics, e.g. [1, 2]. My challenge was to adapt and simplify the project-based learning in order to use it for the first year students in regular mathematics class without any changes to curricula.

2.1 ROBOTIC "PLAYBACK" FOR MATHEMATICS

Four projects for the first year students were developed, two in each semester.

Car distance control The task is formulated as follows: We have a car, which can drive only back and forth. The speed is regulated by the input m to the motor. The value ***m*** can vary from -100 to 100 (maximal speed backwards/forwards) and will be automatically cropped if it exceeds the limits. A sensor is measuring the distance s in cm to obstacles in front of the car. Our task is to find a simplest way to set ***m*** if we know distance to obstacle s in such a way, that the car keeps 50 cm distance to the obstacle. "Simplest way" means here to have one formula for ***m = m(s)*** without a differentiation of possible cases (without if ..., then ...).

The "Playback" was a car-simulation by means of the platform "Open Roberta" [6] which provides a simple pick-and-play environment with a simple programming language for many types of robots (we use the Lego-EV3-car). A student just had to introduce his expression how to set the motor value (see Fig. 1). This simple simulation is good enough at this level. In the class we test the most interesting suggestions on the real Lego-car. We discuss the differences between the simulation and reality thus preparing ourselves to a later project, with improved car modelling, see bellow.

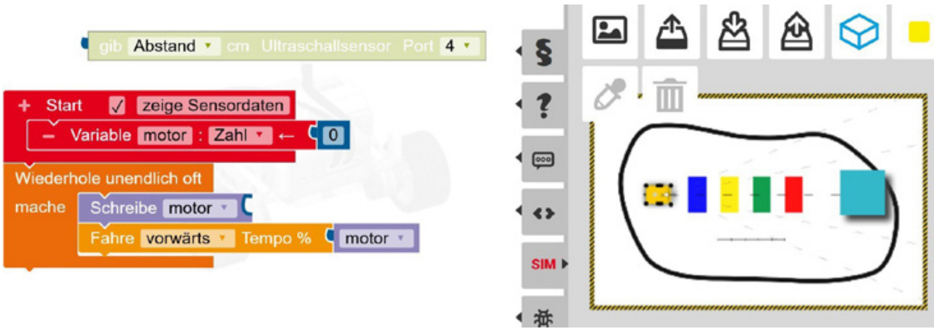

Fig. 1. Open Roberta [6] simulation environment for car project. On the left: prepared code with only the motor setting missing. On the right: prepared scenario with a car and an object in front of it.

Robot-arm with two rotational joints The task is formulated as follows: a robot arm should reach out to a desired position ***(x, y)*** meaning that we need to set the joint angles ***α, β*** as a function of ***(x, y)*** (see Fig. 2). The student can simply introduce his formulas into a prepared Matlab live-script file.

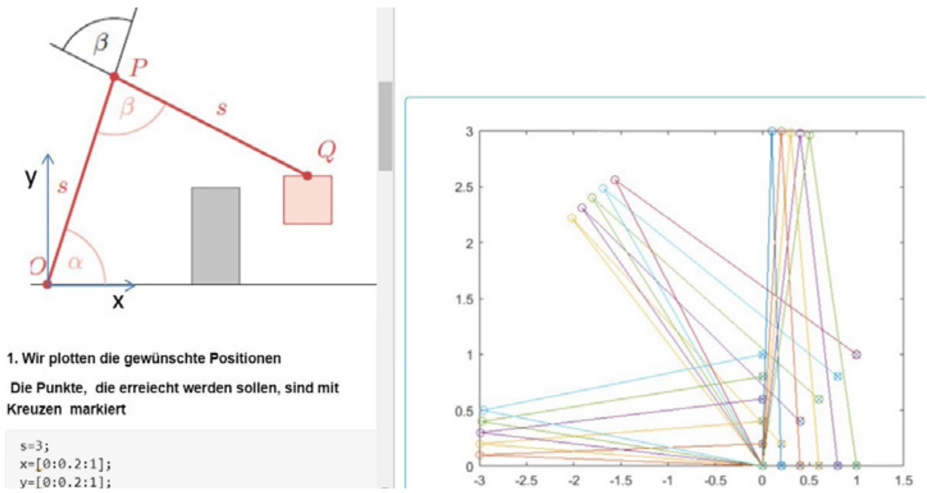

Fig. 2. Matlab live script for a planar rotational joint arm. On the left: a code snippet with a the task [3], on the right: plot of simulation

Modelling car dynamics In the first project student experienced that the simulation of the car by Open Roberta is not precise enough. It doesn't account for delays and friction, so that students can't observe in simulation oscillations and other possible problems of Feedback-Control which they observe on a real Lego-car. Further more, I make clear that knowing a mathematical model helps us to set optimal parameters for car control. Thus the students are motivated to investigate better car modelling. The task is formulated as follows: given is the data sample from the motor $m(t)$ and the corresponding data from the distance sensor $s(t)$ in the case of still-standing obstacle and car driving forth and back. We assume that the two given time series are coupled by following dynamics: $a\ddot{s} + b\dot{s} = m$. Our goal is to find the modelling parameters a, b.

For testing their results students get a Matlab script with prepared plotting and comparing of the model results and the data. Only the values of a, b are missing and has to be set by students.

Optimisation of Feedback-Gain Finally in our last project we use the car model above with a simple proportional feedback m = $k(50 - s)$ leading to dynamics $a\ddot{s} + b\dot{s} = k(50 - s)$ of a car trying to keep distance of 50cm to the obstacle. The task is to find an optimal gain k. Optimal car behaviour means here that the car drives as fast as possible to desired distance of 50cm without oscillating. Open-Roberta has to be replaced now by more precise simulation, and we use a Matlab Simulink for this purpose. Students do not need to learn much about Simulink, because they are provided with a prepared simulation, in which only the gain k has to be adjusted, (see Fig. 3). In the class we also test the results on the real Lego-car.

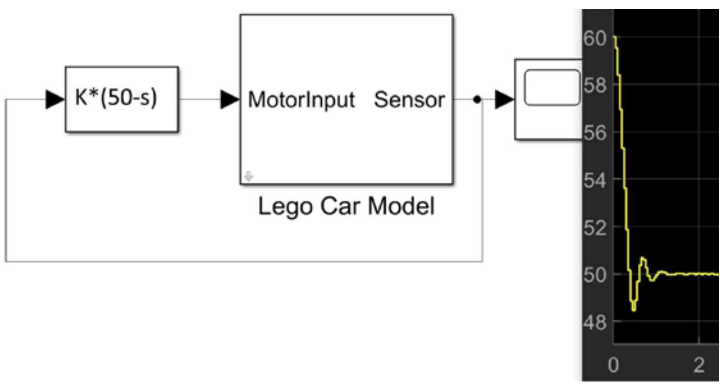

Fig. 3. Simulink Model for testing the optimisation of the feedback-gain k.

2.2 LEARNING BASIC MATHEMATICAL NOTIONS

The main purpose of our project-based learning is not programming and robotics. For this reason all corresponding tasks were possibly blended out by usage of preprepared code and simulation as described above. The main purpose is learning of Mathematics, so what do students learn? I will show what students learn by analysing their difficulties and failures.

Proportionality and slope The first project's challenge is the notion of function and proportionality. Nearly all students write in their reports, that $m(50) = 0$ because if the car is at the distance 50cm from the obstacle it should do nothing. Many decide that $\mathrm{m}(t)$ should be a linear function and take typically $m(0) = 100$ as a second point and than build a formulae $m(s) = As + B$ more or less successfully. Only very few come to conclusion, that the general approach could be proportionality $m(s) = k(50 - s)$. . However understanding proportionality and the role of slope k is fundamental for understanding derivative. The difficulties in doing linearisation have their roots in believing that $y = Ax + B$ is the only way to write a linear equation. Discussing our example and showing its sense and power in application helps to accept later the idea of derivative and linearisation.

Students who have a good background use the freedom to go further. For example one group asked themselves what would happen, if the obstacle is driving away and came to conclusion to use $m(s) = k(50 - s)^3$. Other group used such

complicated model as $m(s) = \frac{200}{1 + e^{-0.2(50-s)}} - 100$.

In this way we become a nice opportunity to discuss all sort of functions and not only the linear ones.

Reading and structuring algebraic expressions, using superposition The challenging part of the second project is dealing with complex trigonometric expressions. Students prefer to write in a line very long expressions without using auxiliary variables. This leads to failures. We discuss how to discover repeating patterns in algebraic expressions, when and why are auxiliary variables beneficent for programming and for doing maths. My experience with such topics as a chain rule shows, that student have a big backlog in understanding substitution and superposition. Thus the time spent at this project is an important preparation for later topics.

Function being solution to differential equation I frequently observe difficulties with general understanding of notion function, input and output. In the first two projects some students give their answers as $s(m)$ or $x = x(\alpha, \beta)$ instead of $m(s)$ and $\alpha(x, y)$ arguing that they solved the problem because they gave the relation between the variables. In the third project we model Lego-car by differential equation and it is crucial to perceive a function as an element. Not only variable x but also a function can be an unknown. Function can also be an input or output of the system, this is an important basic for understanding System-Theory. This is the most difficult part of all projects for the students. They typically start trying to solve a differential equation in a general way for arbitrary parameters instead of inserting the given functions into equation to get the parameters of the model. Because they learn solving equations in the class and it is difficult to break the routine and look from a different prospective. After finding model parameters we test the model with other input $m(t)$ from motor and compare results with the data gathered by Lego-car. This shows to students again, that the function can be an input to the system and on the output we get another function, corresponding to the values of the sensor $s(t)$.

Critical thinking about modelling, precision and optimality Our last project adresses from mathematical point of view the concept of critical damping but it is much more about critical thinking. Indeed, our task is to find an optimal feedback gain for car distance control. Many students expect a precise answer as they are used to from their school days. They are astonished to see that a whole range of values works perfectly well in praxis. I hope that this experience make them more comfortable to work with uncertainty and persuade them to analyse how important the precision is. That it doesn't make sense to always write 5 decimal places in the answer. That mathematics is not only about being precise: Function sketches are aloud and approximations too. Only the final application decides about the necessity and meaningfulness of precision.

3 CONCLUSIONS

Looking back I remember the overwhelming feeling during my first internship after three years at high-school. It was the moment where I finally understood what for did I studied all the theories. Fortunately nowadays students start with internship earlier and my goal was to start meeting reality from the first lessons of mathematics at the high-school. Robotics applications with building software and hardware are very time-consuming. Thus a lot of "playback" was prepared in form of simulations so that only small part has to be added by the student at their homework. A ready Lego car was provided for the tests in the classroom. The main advantage of robotic projects is, that it allows understanding the sense of the whole and gives you the right "story", right context, for learning mathematics. We stick to a real story of a car control and reduce the complexity by restricting the movement of the car, by simplifying the model, and by concentrating on proportional feedback only. Later students will learn better car-models and the power of full control theory. The complexity will naturally increase with time. It is much better to take a real problem and simplify mathematics than to take a toy problem with complex mathematics. Indeed, the difficulties of first-year students are hidden in the basics like proportionality, notion of function and variable, and so on [4]. If you provide classical exercises for these basics you demotivate students, because they feel themselves thrown back to the ground-school. Giving a real story is not only motivating, it also helps to anchor the knowledge in a meaningful context. Students learn that mathematics is not about the most complex formulas with most high precision and they learn to use mathematics here and now.

In the future we plan a quantitative analysis of the method and comparison to similar projects already done by our partners [5] in the framework of European cooperation EUT+ ELaRA.

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PRACTICE-ORIENTED LEARNING WITH FOCUS ON SOCIAL RESPONSIBILITY AND ENVIRONMENTAL SUSTAINABILITY IN ELECTRICAL ENGINEERING

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ABSTRACT

This paper describes a form of service learning at Karlsruhe University of Applied Sciences that is particularly suitable for engineering students. The presented teaching approach combines technical projects with social learning and sustainability topics. The aim is to broaden the students' view of technology and to demonstrate its versatile dimensions. The described format particularly promotes critical thinking among future engineers. They should be encouraged to take responsibility for their technical actions, especially in relation to society as well as nature and the environment. In addition, the participating students improve their interdisciplinary communication and cooperation skills. The teaching project implements aspects of responsible technology design that have not yet been adequately disseminated at universities. The accompanying seminars are suitable for use in other teaching formats. This could set in motion a transformation process in teaching that has not yet taken place in the engineering sciences.

1 INTRODUCTION

It is not only since 2018 that people have been warning about the ecological consequences of technology and calling for sustainable action. What young people from the Friday for Future movement are loudly calling for today has been a recurring theme on various sides of society and science since the 1970s. The best-known publications from this period are probably those of the Club of Romes (Meadows 1972) and the philosopher Hans Jonas (Jonas 2015). Since then, demands have been made for sustainable action that enables people to live well today and in the future. These are primarily directed at technical action. In the past, politics, business and the technical sciences have reacted very hesitantly to such appeals. In Germany, however, the idea of Technology Assessment (TA) has been pursued and institutionalised since that time (Rophol 1996: 172–180). More recently, representatives of TA have tried to involve citizens in technology evaluation and assessment through participatory procedures. TA sees itself as the antithesis of technocratic influences that see democratic decision-making processes as an obstacle to progress (Grunwald and Saretzki 2020, 12–14). At universities of applied sciences, technology assessment is hardly a topic, especially in teaching (Jerchel et al. 2022). Reactions to the major societal problems are evident above all in new technical subject content, that is oriented towards the proposals of politics and business. An education of the person that enables them to take responsibility for ecological as well as social consequences of technology is currently still lacking. The closed nature of the disciplines hinders such education (Hemminger und Eimler 2022). Especially in the study of classical engineering subjects, such as electrical engineering, there is a lack of such content.

In the following, the challenges and problems that engineers face in their studies and careers are outlined using the example of electrical engineering. They are confronted with an ambivalent attitude of society towards technology, which shows both enthusiasm and rejection. In addition to responsible technology development, one of the great challenges of engineering in the future will be to involve society in fundamental decisions. Democratic decisions will become more important for the acceptance of future developments (Grunwald and Saretzki 2020, 11).

Engineering studies have not yet been designed to prepare students for a dialogue with society. Moreover, education in responsibility for ecological as well as social consequences of technology is currently still a deficiency in classical engineering degree programmes, such as electrical engineering. The closed nature of the disciplines hinders such education (Hemminger und Eimler 2022).

A brief description shows the adherence to traditional structures in the study of electrical engineering. These have proven themselves so far. Electrical engineering graduates are in demand and the quality label “German Engineer” does not seem to have lost its power. Classical engineering degree programmes leave little room for a broad view of technology in all its dimensions.

How this can be used to provide impulses for an education that is up to the demanding tasks of the future will be shown below using a best-practice example at Karlsruhe University of Applied Sciences. The approach presented is suitable for disseminating and consolidating topics of technology assessment and sustainability in studies.

2 REQUIREMENTS FOR THE EDUCATION OF FUTURE ELECTRICAL ENGINEERS

Electrical engineering has traditionally been one of the pillars of technical progress. Its main fields of activity include information, energy and automation technology. Electrical engineering achievements have brought society prosperity and many conveniences in everyday and professional life. Today, there are only a few technical systems that can work without electrical engineering. Electrical engineering is seen as a promise for the future that should allow people to stop climate change without restricting their lifestyles. The main problems to be solved are energy generation and distribution as well as energy efficiency.

Deviating from this positive introduction, electrical engineering is identified as one of the major causes of ecological consequences of technology. Problems are primarily identified in the mass use of electrotechnical goods. The sustainable use of resources and the management of the resulting electrical waste are major challenges for companies and society. Contrary to the demand for sustainability, however, technical material systems continue to be developed that cannot be sustainable simply because of material and energy consumption. The demand for energy in particular is growing every year, also due to digitalisation, which is being driven forward from all sides. Engineers are significantly involved in such developments. However, they often lack a holistic awareness that they are shaping the world in their work (Kornwachs 2013, 31). However, their actions are not only in the service of their employers, but also in the service of society, which demands creative and responsible technical solutions to social tasks. Engineers are therefore called upon to oppose developments that cannot be classified as sustainable. For this, they need tools. This is to be seen in a comprehensive education, beyond technical content. This includes the promotion of self-confidence and the teaching of social values. In addition, opportunities should be given to practise communication and argumentation.

Due to the wide range of tasks and a market economy that is stable and geared towards growth despite crises, the labour market is open to graduates of engineering studies, especially electrical engineers. However, contrary to the good labour market situation and the attractive working conditions, interest in the classical engineering sciences is waning. In addition, the discipline of electrical engineering in particular has not yet succeeded in making its studies attractive to women. The acquisition of young engineering scientists is a concern of the federal and state governments as well as of companies and universities. In the corresponding marketing measures, the importance of engineers for solving the problems of the future is pointed out.

Furthermore students are facing high demands of engineering degrees, that lead to high drop-out rates. In classical engineering sciences, an understanding of technology is passed on in the degree course that is traditionally oriented. The study programme is primarily composed of technical subjects, mathematics and computer science as well as the natural sciences. A restriction to such a subject content represents a truncated understanding of technology that excludes the social-human component of technology. For years, scientists from the German Society for Technical Education (DGTB) have been calling for an expansion to include such an area in schools and universities (DGTB Deutsche Gesellschaft für Technische Bildung e.V. 2018). They justify the underrepresentation of the social-human component of technology by a lack of a closed definition of technology. Corresponding general education subjects could also be integrated into higher education studies.

At present, the canon of subjects is aligned with the state of the art and is constantly being adapted. New specialisations or courses of study can arise from such adjustments. At Karlsruhe University of Applied Sciences, a degree programme in “Artificial Intelligence in the Engineering Sciences” is currently being set up and a degree programme in “Green Technology Management” will start in the coming semester. In terms of content, both are oriented towards trends set by the economy and politics. Such new programmes open up the possibility for universities to include other aspects of technical education in order to give more weight to issues of sustainability and responsibility. This would take it out of the hands of chance whether students choose such courses as part of their general studies.

In addition to the content, the didactic design of engineering degree programmes is subject to traditions. Didactic findings are only sporadically incorporated into their teaching. The first results of an ongoing study at Karlsruhe University of Applied Sciences show this at the Faculty of Electrical Engineering and Information Technology. Over the past fifty years, the teaching methods there have proven stable. The classical lecture has been retained. Didactic changes have only become apparent more recently, especially in the area of classical laboratories, which are being replaced by the concept of project-based learning. The Corona pandemic also pushed digital teaching forward. After the regulations were relaxed, however, in most cases there was a return to classical face-to-face teaching. It is difficult to permanently implement didactic methods that have already been tried and tested if they break with traditional teaching routines. At colleges and universities, it is generally considered difficult to permanently implement transformation processes in teaching. Especially when they intervene in the structures of the departments (Reinders 2010, 531; Miller et al. 2019; Ihsen 1999). For a permanent implementation of teaching-learning concepts, it is profitable to gain the approval of as many teachers as possible in various ways. One way to achieve this is by presenting examples of best practice (Miller et al. 2019).

3 SOCIAL LEARNING AND STIMULATION OF CRITICAL THINKING USING THE EXAMPLE OF H.ERT.Z SERVICE LEARNING

Karlsruhe University of Applied Sciences (HKA) is meeting the challenges described above with the project Hochschuloffenes ElektroTechnik Zentrums (H.ErT.Z). The primary goal of the offerings in the H.ErT.Z project is to educate students to assume responsibility under a holistic view of technology. The future engineers are to be prepared to democratically help shape the "social contract" (WBGU 2011) for the sustainability turnaround in the future.

The H.ErT.Z project was made possible by financial support from the state of Baden-Württemberg (BW) from the funding lines Wissenschaft Lehren und Lernen (WILLE) and Lehr-Lern-Labore. The offers are available to all students of the HKA, even after the end of a five-year funding period (2016 - 2020). Another funding application made it possible to permanently finance a job through the state of BW. This job is to be used to expand the teaching projects initiated and implemented today and to implement them in further courses. The H.ErT.Z Centre can be seen as a nucleus for teaching innovation at the HKA, especially at the Faculty of Electrical Engineering and Information Technology EIT.

The various teaching-learning projects are designed to develop the following knowledge and skills of the students:

Ability to learn in a self-organised way.

- Ability to think critically.
- Awareness of their own responsibility.
- Knowledge of social norms and values, also on a global level.
- Skills in subject-specific as well as interdisciplinary communication.
- Willingness to participate in societal discourses and in the technical enlightenment of society.
- Courage for reasonable self-determination.
- Personal skills for co-determination as well as solidarity.

The overall concept of H.ErT.Z is based on three pillars.

Electrical engineering learning centre with attached laboratory: An electrical engineering learning centre is available to students in the basic studies. The concept of learning centres has proven itself at the HKA. They are also set up at the EIT Faculty for the subject areas of mathematics and digital technology. The learning centres promote students' self-organised learning and strengthen their subject knowledge. The support in the H.ErT.Z learning centre follows the principle of minimal assistance (Aebli 1976)1[1] . In addition to content instruction, especially strategic instruction, in the fundamentals of electrical engineering, students will find support in the Learning Center for their writing projects. The learning centre has an experimental laboratory (LivingLab). During consultations, it can be used to eliminate technical misconceptions. In addition, practical events and projects

1 This principle was originally developed by the Swiss Hans Aebli. The basic principle of giving detailed content help only minimally is particularly suitable for project work.

for study orientation take place there. The lab can be used freely by students outside of the courses. These learning opportunities are part of a wide range of measures that help students at the HKA to cope with their demanding studies.

Digital learning: This offerings are to be considered as the second pillar. They initially follow the same goal as the learning centre. For this purpose, self-assessment exercises were developed in cooperation with the Centre for Teaching Innovation and teachers at the university. These are programmed in STACK [1] and are offered within the university via Ilias.[2] Other digital teaching and learning tools were developed with the aim of making didactically well-prepared content available to the general public. The internet platform H.ErT.Z online provides interactive scripts, instructional videos and applications on the fundamentals of electrical engineering as Open Educational Resources (OER).[3] The start page shown in Figure 1 provides an overview of the content. With this offer, the HKA is pursuing sustainability goal 4, which calls for high-quality education for all. The download figures for the scripts show a high level of use outside the university. In the lock-down phases during the Covid19 pandemic, the teaching materials were particularly popular. Not only subject content is presented on the platform. A timeline on the history of electrical engineering demonstrates its cultural significance.

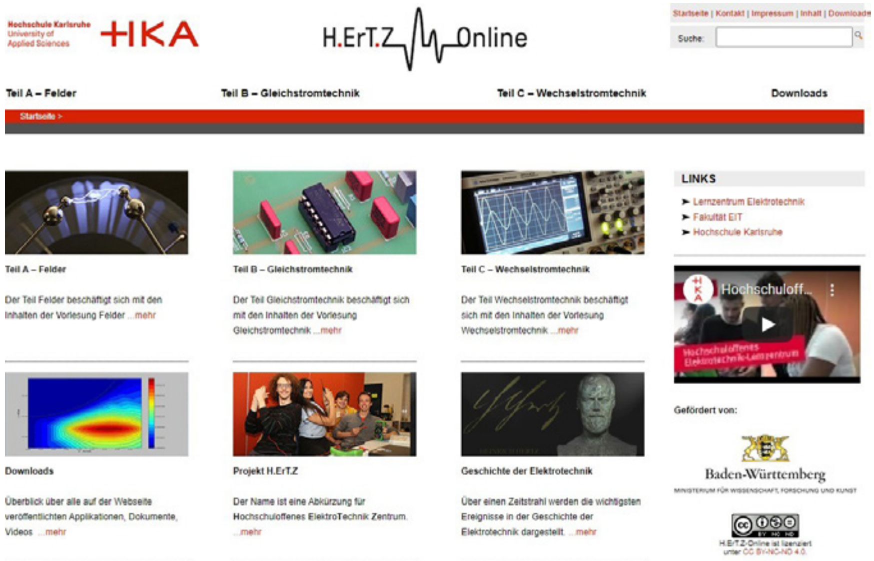

Figure 1: Start screen of the internet platform H.ErT.Z online.

1 STACK stands for System for Teaching and Assessment using Computer algebra Kernel. STACK allows mathematical expressions to be entered into Computer Aided Assessments CAA and the results to be checked automatically. STACK was developed for Moodle and Ilias. More information can be found on the Ilias website: https://docu.ilias.de/goto_docu_pg_75134_5824.html (timeliness verified 15-APR-2022)

2 The exercise pool can be passed on to interested parties.

3 H.ErT.Z online hertz can be found at this link:https://www.eit.hs-karlsruhe.de/hertz/quicklink/startseite.html (timeliness verified 15-APR-2022)

Social Learning: The third pillar of the H.ErT.Z Centre primarily serves social learning. The courses offered in this area address the social and ecological effects of technical action in order to stimulate sustainable and socially beneficial innovation. One such format is H.ErT.Z Service Learning (SL). The basic concept of this form of teaching and learning combines technical learning with social engagement and critical thinking. An essential component of the SL is the students reflection on their project experience. H.ErT.Z Service Learning will be presented in more detail below.

4 H.ERT.Z SERVICE LEARNING

SL has been established at many colleges and universities, in various forms, for some years now. A large number of these educational institutions are represented on the website of the "„Hochschulnetzwerk Bildung durch Verantwortung“ [4]. If you follow the links to the university pages, you can see that SL projects are mostly represented in the fields of social sciences, economics and humanities. SL is offered comparatively little in the area of technology. In this area, projects can be found mainly in urban planning, computer science or medical technology fields. SL projects in electrical engineering are offered rather rarely. The increase in such learning settings is a clear sign that society is in transition. The website of the Ruhr-West University of Applied Sciences states that today's students prefer tasks and projects whose social added value is recognizable.[5]This attitude is likely to increase with the next generation taking to the streets for their rights. Such demands can be met via the dissemination of SL.

At HKA, SL projects are in principle offered to all interested students. During the trial phase, however, they were carried out exclusively at the EIT faculty. There they are also integrated into the curriculum. The SL projects are recognized via the module Scientific Work and assessed with six ECTS points. The performance is measured by the obligatory reflection units, the project presentation as well as a project report. Technical project supervision is provided by professors of the faculty. The project flow is described in the following diagram (Figure 2). The diagram is based on an electronic circuit diagram. This is intended to pick up people who are more committed to technical thinking. Unfortunately, the project flow is only available in German so far.

4 HKA has not yet joined the network. This is still under discussion. The website is available at https://www.bildung-durch-verantwortung.de/ (timeliness verified 15-APR-2022).

5 https://www.hochschule-ruhr-west.de/die-hrw/lehre-an-der-hrw/hochschuldidaktik/service-learning/ (timeliness verified 15-APR-2022).

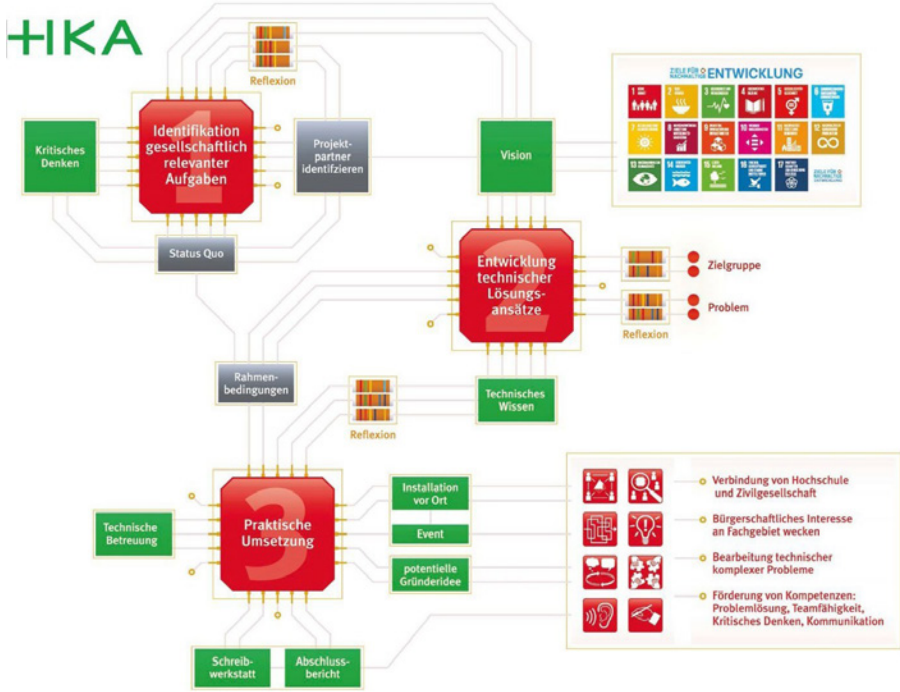

Figure 2: Flow chart of service learning at Karlsruhe University of Applied Sciences. Graphic: Norbert Gatz, Idea: Anna Krez

The project process is divided into three phases.

Phase 1: In this phase, projects are proposed, which are first checked to see whether the conditions for SL are met. Tasks for SL can be proposed by local and regional civil society organisations. Corresponding proposals can also be submitted by students and university members. The H.ErT.Z Centre plays an intermediary role during the acquisition of projects. Projects for the H.ErT.Z Service Learning are subject to the condition that the tasks allow for technically high-quality projects. If no students are involved in the selected proposals, the SL projects are put out to tender. The awarding of the project is followed by an initial seminar. There, the concept of SL is presented and the social role of engineers for social transformation is reflected upon.

Phase 2: In the second phase, the technical tasks of the project proposals are identified and implemented. The procedure is based on the methods of usual project work. Problems are identified, solutions designed, selected, implemented and optimised. Regular technical meetings are held for this purpose. For the implementation of the technical projects in SL, quality standards were further developed from the perspective of sustainability. These follow the Design for Six Sigma DFSS method and are made available to students as a handout. In it, guiding questions are given to them, which they can use to reflect on their technical actions. Students are encouraged to document their reflections already in the design phase and to pay attention to sustainability. The following table is an excerpt from the handout.

Primary sustainability objectives in the development of technical projects. Criteria for assessment and implementation of designs	
12 RESPONSIBLE CONSUMPTION AND PRODUCTION	• Do not order materials on spec. • Clarify which materials are already available. • Dismantle experimental set-ups. • Dispose of defective components properly. • Ensure short transport routes. • Prefer local manufacturers
8 DECENT WORK AND ECONOMIC GROWTH	• Observe supply chains diligence obligations! Even if only to a limited extent so far, there are certified sources that show sustainability.
13 CLIMATE ACTION	• Assess the energy efficiency of your designs. • Compare energy efficiency of individual assemblies before ordering.

Table 1: Guiding sustainability goals for technical project work

Workstations are available in the LivingLab for the implementation of the technical projects. Parallel to the technical development, regular meetings are held with the cooperation partners. In addition, further seminars are offered to strengthen critical thinking.

Phase 3: During this final phase, the technical projects are applied or demonstrated to the social project partners. The form in which this step is implemented depends on the tasks and partners. The H.ErT.Z Service Learning is finally concluded with a project report. Support for scientific writing is provided by a writing seminar at the H.ErT.Z Learning Centre. The students are encouraged to not only document their technical project in the report, but also to reflect on their technical actions with regard to sustainability as well as their project experience.

When introducing SL in technical subjects, care should be taken not to burden students with a large additional workload compared to the usual project work. The demands of the technical projects should also be comparable. This is not only necessary from a student perspective. The recognition of SL by other teachers at the university also depends on the technical standard of the projects. Furthermore, it should be considered that there should be a staff position that takes over the organisation and coordination of SL. At least one additional person should also be included for the reflection units and seminars. However, these seminars could also be offered through the Studium Generale and be available to all students at the university. The workload for H.ErT.Z Service Learning the 6 CP/ECTS is distributed as follows.

Task	Work effort per person
Implementation of technical project	100 h
Seminar "Scientific Writing“	2 h
Project report	30 h
Seminars and exchange with project partners	18 h
Cooperation and implementation on-site	30 h
Total hours	180 h

Tabel 2: Dividing up the hours of work in service learning

4.1 PERIODS OF REFLECTION ON RESPONSIBLE TECHNOLOGY DESIGN

Students' reflection on their experiences in the projects is one of the quality criteria of SL.[6]This opens up a way for universities of applied sciences to advance issues of sustainability. In H.ErT.Z Service-Learning, the topics of reflection therefore go beyond the experiences in the project. In seminars, competences are strengthened that have so far been excluded from regular studies. The reflection units are based on theories of critical education theory (Koneffke 1982). Reflection is practised in at least five seminar units accompanying the project. There, the participating students are taught values that are intended to give them orientation for resource-conserving technical action. The content of the seminars is based on the 17 Sustainable Development Goals. The students gain an initial understanding of how to assess the risks of their technical solutions.

The seminars are essentially intended to raise students' awareness that social system change is necessary at all levels in order to keep the world livable for people. In the interactive events, the students ask themselves what responsibility they have towards society as future engineers and what influence they can have on technical developments as individuals. In connection with their experiences in service learning, they should answer the question of why it is relevant for them to actively help shape society.

4.2 KNOWLEDGE TRANSFER - THE THIRD MISSION OF UNIVERSITIES

Social needs and interests can only be incorporated into technical solutions if new knowledge is disseminated in civil society. This can create the basis for participatory technology development. Citizens are open to such participation and interested in contributing their own expertise to solve current and future tasks. This willingness is also increasingly used in TA (Frey et al. 2020). Universities and colleges can provide the necessary knowledge transfer by making use of their expanded educational mandate (Kretschmer 2017). This broad field includes activities such as pedagogical outreach work and the promotion of young

6 These are aligned with the quality criteria of the Quality Editorial Group of the Higher Education Network "Education through Responsibility", which in turn are based on the quality standards of Learning through Engagement. https://www.service-learning.de/lernen-durch-engagement/lde-qualitaetsstandards (timeliness verified 15-APR-2022)

researchers as well as democratic participation intentions in the definition of specialised tasks. Service-learning projects offer such spaces of opportunities for social participation in technology development as well as for science communication (Klischat 2018).

5 AN EXAMPLE OF SL AT THE HKA - COOPERATION WITH THE KARLSRUHE CITY YOUTH COMMITTEE

In the following, a project of H.ErT.Z Service-Learning is described in more detail, which has been carried out under different tasks since 2017. It is a cooperation with the Karlsruhe City Youth Committee (Stja), which has also been taking place in collaboration with students from the Karlsruhe University of Education since 2019. The Stja organises summer holiday programmes in Karlsruhe, to which the children and youth city Karlopolis [7] belongs. This offer for children between the ages of 8 and 13 has existed since 2015 and follows the concept of a simulation game. Under very reduced guidance, children reenact social, political and economic life in a city and practise democratic and appreciative cooperation. Almost 700 children take part in this programme during two holiday weeks. In Karlopolis, children also get an insight into the different professions of the numerous companies and institutions. One of these companies was the energy and water company, which is guided by service learning students as experts.

Figure 3: Children at Karlopolis: Building bicycle generator and wind turbine

In Karlopolis, the technical systems and installations developed by the students during the semester were built together with the children. The children slipped into professional roles under which they were introduced to the topics of sustainable energy production and water management. They also had the opportunity to get to grips with electrical engineering, computer science and mechanics. The specially developed systems included a solar house, a wind turbine, bicycle generators and battery storage. In the case of water supply, the focus was on the sensible use of service water.

During the semester, the students dealt intensively with sustainability topics on energy production and distribution as well as water supply. This made them experts who, in addition to their technical knowledge and skills, were able to communicate these topics to the children. The necessary basic pedagogical knowledge was imparted to the technical experts by students from the Karlsruhe University of Education. This cooperation with the

7 You will find more informations under https://karlopolis.de/ (timeliness verified 15-APR-2022)

Service-Learning of the Department of Childhood Education at the Karlsruhe University of Education has been in place since 2019. The students already form interdisciplinary learning tandems during the semester in order to jointly generate ideas for teaching technology and sustainable action. Both sides benefit from this collaboration through the insights gained from the respective foreign subject cultures.

Due to the pandemic-related restrictions on large-scale events, the format of the play city was replaced by a decentralised holiday offer. In 2020 and 2021, students presented their service-learning projects around the topics of "renewable energies and resource conservation" for one week in the form of a research camp. Technically demanding projects, such as the use of residual energy in old batteries in LED headlamps or the further development of a mobile water pump truck, not only challenged the students' technical know-how. The cooperation with the Karlsruhe University of Education was continued. The systematic reflection units offered to the students made an essential contribution to understanding a larger sustainability context. The implementation of the SL projects during the Covid19 pandemic took place at a particularly tense time for families. In the final reflection, almost all students were particularly positive about the fact that they had the impression that they had really made a socially important contribution through this holiday action. Both, for the children and their families.

Figure 4: Impressions of the "relax research camp" on the university campus

Sustainability of the projects

The technical project works that have been created so far within the framework of Karlopolis or Relax are characterised by a special sustainability compared to usual project works. On the one hand, they are always further developed and expanded by subsequent projects. On the other hand, they can be adapted and used for further projects. Here are two examples.

In the solar house already mentioned, which was developed for Karlopolis, there is a battery system as well as an electronic unit through which the energy feed from different sources as well as the use of this energy can be monitored and controlled. From this implementation, the idea of a "travelling solar house" with similar characteristics developed. This project led to the "Solartruck" project. For this, electric scooters were equipped with 6 solar modules with a total output of 2200 watts. With the generated voltage of 24 volts, electrical devices can be operated directly. In addition, an alternating voltage of 230 V is generated from the battery's direct voltage. In the meantime, the battery system's state of charge can be called up via the internet. In addition to its use in SL projects, the solar truck is used for knowledge transfer to society. The integrated technology is used to communicate the topics of renewable energy and electric mobility. Its large loading area makes it possible to present larger exhibits and experiments directly on site at schools, trade fairs or in public spaces.

Another Karlopolis project, the bicycle generator, led to cooperation with the Badische Landesbühne. In this SL project, bicycle generators were used to supply the stage lighting with electricity. In the play "What on Earth?!" a dystopian future is depicted. Teenagers who grew up on the moon want to return to earth. Their goal is to find out why humans had to flee the earth. To prevent this from happening, it is imperative to encourage students to act in a sustainable, reflective way.

The sustainability of SL does not only have to refer to the project work developed. SL can have a lasting impact on teaching in the various subject areas. The concept of promoting competences in critical thinking and in reflecting on one's own technical actions can easily be transferred to other teaching formats and events. To this end, the H.ErT.Z Centre is currently compiling a kind of "toolbox". It will describe relevant concepts that can also be integrated into traditional teaching. Corresponding basic elements have already been created for the study entry and orientation phase at the EIT faculty.

6 CONCLUSION

The implementation of project learning as service learning can provide important impulses for university teaching that brings together individual learning with overall societal goals. Under a critical understanding of education, SL is particularly suitable for establishing topics of technology assessment and sustainable technology development at universities. SL makes it possible to initially establish these contents without changing the subject canon. If the students' reflection does not only evaluate the technical project, but also addresses sustainability issues, this content can also be used in other teaching formats. SL could set change processes in motion and drive a transformation of teaching, which would be particularly desirable in engineering sciences.

For universities of applied sciences, this format is of interest primarily because of the transfer of knowledge to society. By presenting and communicating current technologies, SL can stimulate public processes through which future technologies can be democratically shaped.

In the process of imparting knowledge, SL can also be seen as a marketing event in which universities can draw attention to themselves. It is hoped that the extracurricular communication of technology to children and young people in particular will increase interest in engineering subjects. Since a comprehensive view of technology is given, it is also hoped that the image of technical professions among girls and young women will change. In particular, the experience that technology is not only interesting and can be fun, but is a cultural asset that can be shaped, could spark a lasting interest in studying engineering.

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CAPSTONE IMPLEMENTATION AS A PROJECT-BASED LEARNING COURSE IN ENGINEERING TECHNOLOGY PROGRAMS

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ABSTRACT

Learning by doing or applied learning has gained increasing interest from different institutions and parties across the globe. Various studies and research have shown that such learning environments can increase students' retention, interests, and their way of thinking. Techniques vary widely from small classrooms numerical activity, into larger groups assignments, in-class or online threaded discussions, to larger scale semester or year-long projects. Regardless of the method or activity used, academic institutions have commitment to meet ABET learning outcomes which impose some constraints on the implementation of such activities in the courses. Capstone projects conducted by senior year students offer a valuable opportunity for students in their graduation semester/s to apply concepts and knowledge gained throughout their college experience.

This paper examines project-based learning (PBL) implementation in a capstone project course sequence in the School of Engineering Technology at Purdue University. The paper discusses the implemented course structure over two semesters introducing the major goals and milestones that students need to achieve. Various assessments methods are presented linking the course outcomes to ABET learning outcomes. Such assessment methods include technical writing, visual aids, presentation skills in addition to project design and implementation. The projects are designed with six milestone deliverables (called "Gates") throughout the two-semester course. Key elements include high level educational goals for capstone including brainstorming, a marketing survey, design specifications, system development and testing. The design and implementation of the projects focus on learning processes where students can apply knowledge and techniques, design systems, improve written and oral communication skills while working in a team-oriented environment.

Keywords:
Active Learning, Project-Based, Capstone Projects, ABET Outcomes, Assessment.

1 INTRODUCTION

The higher education learning processes and needs have been changing to produce competent practitioners who will be prepared for the multifaceted challenges of current technological advancements. According to a study conducted by Purdue University in 2013 [1], the top skills and requirements that employers are looking for when recruiting new college graduates were innovation, followed by problem solving in diverse settings, then critical thinking, and complex problem solving. These various competencies that employers expect from graduates are reported in [1] and are presented in Table 1.

Today's real-world problems are more global and typically are not confined to a single discipline. The knowledge needed by engineering or engineering technology graduates joining the workforce comes from different domains and disciplines. According to a Purdue University survey of employers in 2013, skills and competencies that employers are seeking from recent graduates include: innovation as a priority, followed by problem solving in diverse settings, critical thinking, and complex problem solving [1]. The survey revealed that innovation, critical thinking, and complex problem solving are becoming more important for employers. To meet these new challenges, active learning methods provide a rich environment with the many ways that it can be offered such as: design projects, technology driven homework assignments, classroom exercises, working problems in small groups, guided and facilitated discussions, online quizzes, online threaded discussions, students presenting new material to the rest of the class, discussion-based learning, and plant tours.

Competency	Employers Agreement Percentage
Innovation is a priority	95% of employers
Broad learning (liberal and sciences)	80%
Liberal and Applied Learning (collaborative problem solving, research, internship, senior projects, community engagement)	Strongly agree
E-portfolios would add value	83%
Knowledge of Human Cultures and the Physical and Natural World * Broad knowledge in the liberal arts and sciences * Global issues and knowledge about societies and cultures outside the US * Knowledge about science and technology	80% 78% 56%
Intellectual and Practical Skills * Critical thinking and analytical reasoning * Complex problem solving * Written and oral communication * Information literacy * Innovation and creativity * Teamwork skills in diverse groups * Quantitative reasoning * Direct experience with community problem solving * Applied knowledge in real-world settings	 82% 81% 80% 72% 71% 67% 55% 86% 78%
Personal and Social Responsibility * Problem solving in diverse settings * Ethical issues/public debates important in their field * Civic knowledge, skills, and judgement essential for contributing to the community and to our democratic society * Ethical decision making 64%	 91% 87% 82% 64%

Table 1. Survey for employers' expectations in new college graduate skills [1]

Wlodkowski [2] indicated that analyzing and studying real life problems are essential components of any problem-based learning (PBL) environment. These motivate critical thinking, collaboration, and professional skills. Weber [3] indicated that it is important for PBL to have defined rubrics for success in order to meet educational goals. It is important to define achievable and reasonable rubrics that the students can understand and achieve successfully.

Despite the proven evidence of the positive effect of project-based learning and learn-by-doing on students learning and success, but it is still not widely used across academic institutions because of the risks and challenges that accompany such learning environments. Some of these challenges and risks, related to students, teachers and institutions, are shown in Figure 1 summarizing findings of a study done by [4]. Such major changes in courses can face resistance from faculty, students and the institution itself. In other words, implementing such dynamic learning environments require participation from the students and faculty, faculty support and additional effort, higher management support. To implement PBL learning techniques, the instructor should design the course to meet the course learning outcomes set by the college for different courses and should meet the various outcomes set by accrediting incorporations such as ABET. This requires not only effort and time, but continuous learning and professional development. However, designing the course with a set of goals is not all what the faculty needs to do, but rather they need to guide the students to manage the time and help in resolving conflicts that can arise between different team members. This raises the significance of carefully forming student groups to be dynamic groups whose knowledge should be constructive towards the success of the project. Even with the commitment from both the students and the faculty to do what they are supposed to do, the higher management support such as from the colleges' dean or provost office would be needed to approve and support such big changes in teaching delivery methods. For example, PBL would require new teaching tools, more faculty to help manage the various team, and flexible classroom setup which all needs not only funding but logistic support, as well, such as professional development to the faculty.

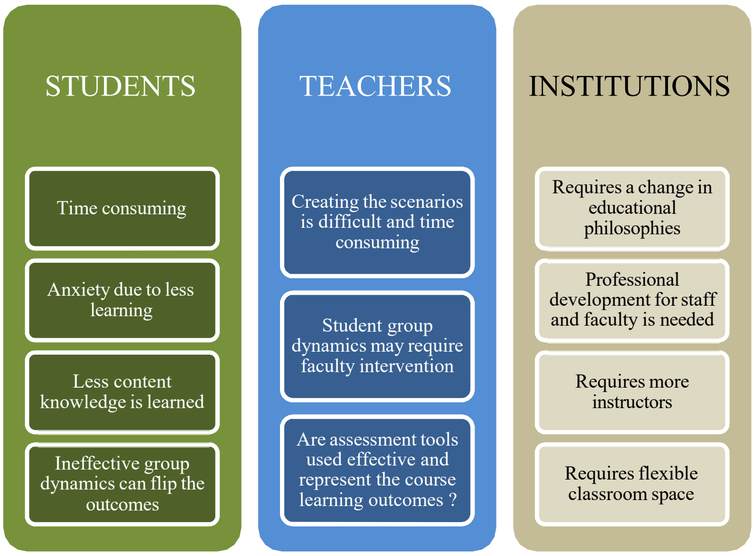

Fig. 1. PBL associated risks and challenges

The capstone course at Purdue Polytechnic Institute is offered over two academic semesters. The needed skills to define, design and develop engineering technology solutions are introduced and developed. Planning and designing alternatives that meet cost, performance, and user-interface goals are emphasized while considering different design approaches. In addition, project planning, scheduling, and management techniques are studied. Teamwork, global and societal concerns, and professional ethics are integrated into course projects.

2 COURSE GOALS

Students successfully completing the capstone projects are expected to have identified a problem, researched possible solutions, brainstormed feasible solution, designed preliminary solution, designed testing plans, tested proposed solutions and assessed the outcomes versus the identified specifications. Through the design, building and testing process, the student should learn the following:

- Strategies for the creation and development of ideas for projects
- Importance of recognizing problems and problem definition
- Writing of project descriptions and specifications
- Maintaining a technical journal
- Sources of parts and procurement methods
- Examples and use of project schedules, time charts or Gantt chart
- Team dynamics and how to interact on a project team
- Sources of information and reading manufacturer's specifications
- Formal presentation of technical material using computer presentations
- Designing and building a significant technical project
- Problem solving of technical, logistic and budget aspects of the project
- Collaboration and consultation with instructor, faculty, outside experts and peers
- Evaluation, testing, and demonstration of the operation of a technical project
- Documentation of a project in the form of progress reports and final report

3 COURSE STRUCTURE AND ASSESSMENT

The capstone project is designed in a way to have a prototype for the proposed solution designed during the first semester, whereas system implementation, testing and product improvement are done during the second semester as shown in Figure 2 and Figure 3. Table 2 shows the different milestones or gates to be accomplished. Gate 1 through Gate 3 were done during the first semester, whereas Gate 4 through Gate 6 were done during the second semester. Different goals and tasks were required between the different gates including market analysis, decision matrix, product specifications, and testing plan.

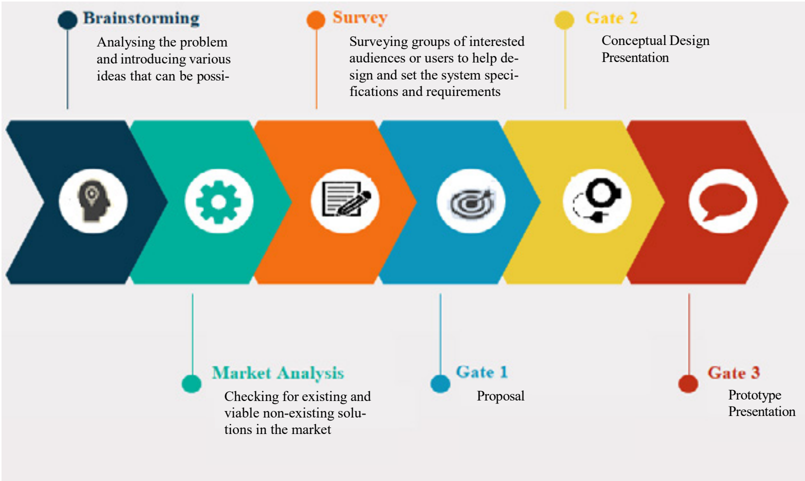

Fig. 2. Project timeline and milestones done during the first semester

During the first semester, the teams are formed and a project topic is identified. Capstone projects are done at Purdue Polytechnic Institute combining students from different majors including Mechanical Engineering Technology, Engineering Technology, Electrical Engineering Technology and Manufacturing Engineering Technology. This opens more opportunities for students to work on diverse projects and not just addressing a problem that falls in their domain only. The typical practice is to source projects from industry partners who provide a list of different topics and problems to be addressed. Following the team formation and topic selection, approval by the course instructor, brainstorming and market analysis are done to search the market for existing and viable non-existing solutions. The non-existing solutions help the teams identify issues in existing designs and explore areas for improvement. Following the market analysis, the teams prepare a survey and identify project stakeholders to assess marketability and desired features for their project/product.

Gate 1	Project Proposals
Gate 2	Conceptual Design
Gate 3	Prototype Demonstration
Gate 4	Critical Design Review
Gate 5	Project Presentations
Gate 6	Final Report

Table 2. Scheduled Gates

After surveying and collecting different opinions, the teams analyze the data, identify specifications, build a decision matrix and begin the system overview using a block diagram t. The main question that the teams should ask themselves when determining system needs and specifications is the following:

"What key measures will indicate success for the project?"

Each specification identified would serve as a performance indicator upon which the teams need to build a testing plan and assessment. The testing plan and methods to evaluate the results against the defined specifications is the core work of the second semester.

Following the preliminary research work, including the market analysis, clients surveying, brainstorming the initial solution for the problem, the teams submit a formal project proposal and present it to the course instructor and other teams in the course. This milestone represents Gate 1 with rubrics shown in Table 3 including preliminary information to get the project initiated such as problem definition, market analysis and existing solutions. In addition to this, the instructor evaluates the team's written communication skills and visuals used in both the proposal report and the presentation. These rubrics along with the grading scale and weights applied to the different performance indicators are shown in Table 3. The performance indicators in all gates are assessed on a scale of 0-4 with: 0-1 being at the deficient level, 2-2.5 at the developing level, 3 at the emerging level and above 3 at the proficient levels. These levels are used for ABET outcomes assessment.

Fig. 3. Project timeline and milestones during the second semester

Name(s):		Proficient (4)	(3.5)	Emerging (3)	(2.5)	Developing (2)	(1)	Deficient (0)	Score (0-4)	x Weighting	Category Points	NEW ABET
Project Title:												
Problem Definition	The problem is clearly stated, the background and theory understood. Drawings and pictures included as appropriate to explain problem.								?	8	?	3.1 PI1
Prior Art	Sufficient research has been done to seek existing solutions and the strengths and weaknesses of those solutions have been defined.								?	5	?	3.1 PI1
Preliminary Solution/ Challenges and Contraints	A realistic solution for the problem has been presented and the challenges and other constraints are defined.								?	5	?	3.1 PI1
Market Analysis	The report discusses the demographics of the target user and potential sales. A survey of potential users is included								?	5	?	
Written Communication	Document is well organized, grammatically correct, sentence structure is clear, and there are no misspelling/wrong word or run on sentences.								?	5	?	
Visuals	Document uses visual and graphical techniques to present ideas. Figures are properly titled and annotated. Tables are properly titled. Units are used properly. Flow charts and block diagrams are easy to follow.								?	5	?	
References and Acknowledgement of Sources	Sources of materials (pictures, specifications, articles) properly identified and acknowledged								?	4.5	?	
COMMENTS:										Total (150 max)	?	Average Level for ABET:

Table 3. Gate 1 (Proposal) Rubric (Highlighted rubrics are used to assess ABET outcome 3.1 as shown in the ABET assessment section)

Following Gate 1, the students start articulating the conceptual design for their projects discussing deeper details about the design and the proposed solution/s, its strengths and weaknesses and present it four weeks after presenting the proposal. During these four weeks, the teams formulate the problem and refine the problem statement to meet the clients' needs, work on introducing a conceptual design for the problem by analyzing various solutions through a decision matrix comparison. A detailed proposed work schedule, bill of material and estimated manpower and time is presented in Gate 2 – Conceptual Design. The rubrics for the conceptual design presented in Gate 2 are shown in Table 4.

Name(s):		Proficient (4)	(3.5)	Emerging (3)	(2.5)	Developing (2)	(1)	**Deficient (0)**	**Score (0-4)**	**x Weighting**	**Category Points**	**ABET**
Project Title:												
Problem Definition	The problem is clearly stated, the background and theory understood. Drawings and pictures included as appropriate to explain problem.								?	3	?	
Decision Matrix	Multiple options for solving the problem are considered and benefits and weaknesses are evaluated. A decision matrix with weighting factors justified is presented and design selection supported.								?	10	?	3.1 - PI1
Initial Design Concept	An initial design is presented based upon information from prior art, decision matrix and market survey input.								?	8	?	3.1 - PI1
Work Breakdown	The Gantt chart shows appropriate tasks organization, maintains options and foresees interaction including testing. The Gantt chart should be completed through both semesters.								?	8	?	
Oral Communication	Document is well organized, grammatically correct, sentence structure is clear, and there are no misspelling/ wrong word or run on sentences.								?	8	?	
Visuals	Document uses visual and graphical techniques to present ideas. Figures are properly titled and annotated. Tables are properly titled. Units are used properly. Flow charts and block diagrams are easy to follow.								?	8	?	
References and Acknowledgement of Sources	Sources of materials (pictures, specifications, articles) properly identified and acknowledged								?	7	?	
COMMENTS:										Total (200 max)	0	Average Level

Table 4. Gate 2 (Conceptual Design) Rubric (Highlighted rubrics are used to assess ABET outcome 3.1 as shown in ABET Assessment section)

Gate 3 wraps up the work of the first semester with students demonstrating prototypes for their work. At this stage, not all performance indicators must be fulfilled and the prototypes do not necessarily have to be in full working conditions. Instead, the teams are required to demonstrate proof of concept and should show that they are qualified to continue to the next semester to implement the concepts into final design. As shown in the rubrics for Gate 3 in Table 5, the success factors for this milestone are based on whether the prototype works as reflected in the proposal and conceptual design. The teams' effectiveness working in teams, task organization and work break down along with presentation skills are all assessed as part of Gate 3 end of the first semester. Gate 3 or the prototype presentation is very critical as it represents an employee presenting his case study to his superior or line managers to get their approval for moving forward with his research or product development ideas and to get funds approved and allocated.

With the teams having more solid background and basis for their solution design, the teams begin their second semester by breaking down the work for the second semester with more details, assigning manpower and time for the proposed tasks needed to build a detailed testing plan and to carry it out. Thus, the first task in the second semester is to present a detailed Gantt chart, identifying gaps and tasks that were not completed in the first semester and projecting new time frame to meet the current semester deadlines and milestones. After submitting a detailed project schedule, the teams start detailing a thorough testing plan against each and every specification or performance indicator identified during the first semester. The teams then start conducting these tests before being able to present their critical design in Gate 4. The rubrics for Gate 4 are shown in Table 6.

Name(s):		Proficient (4)	(3.5)	Emerging (3)	(2.5)	Developing (2)	(1)	Deficient (0)	**Score (0-4)**	**x Weighting**	**Category Points**	**ABET**
Project Title:												
Prototype Functions	Although there may be some minor issues, the prototype functions and there are no major hurdles in the way.								?	20	?	3.1 - PI2
Specifications are Met	The prototype meets the primary design specifications.								?	10	?	3.1-PI2
Task Organization	The student has a clear plan for what tasks need to be completed in order to finish the project by the deadline. Work breakdown structure is detailed and milestonesappropriate enough to control project.								?	10	?	
Oral Communication	The student uses proper grammar in the demonstration of the prototype. The presentation is organized and the student appears confident in their knowledge of the subject. Any questions posed are well answered.								?	10	?	
COMMENTS:										**Total (200 max)**	?	**Average Level for ABET:**

Table 5. Gate 3 (Prototype Presentation) Rubric (Highlighted rubrics are used to assess ABET outcome 3.1 as shown in ABET Assessment section)

Student Name(s):		Proficient (4)	(3.5)	Emerging (3)	(2.5)	Developing (2)	(1)	Deficient (0)	Score (0-4)	x Weighting	Category Points	ABET
Project Title:												
System Design	The system configuration, interconnects and interfaces are fully defined and understood.*								?	5	?	
Detailed Design	Design package is 100% complete and includes mechanical drawings with dimensions, schematics, PCB's designed, and software outlined.*								?	5	?	3.1 - PI1
Test Plan	Testing of all critical performance parameters are defined, as are plans for ergonomic considerations (where applicable).								?	5	?	3.1 - PI1
Bill of Materials	A complete bill of materials is presented.								?	5	?	
Oral Communication	The student uses proper grammar in the demostration of the prototype. The presentation is organized and the student appears confident in their knowledge of the subject. Any questions posed are well answered.								?	5	?	
COMMENTS:										**Total (100 max)**	**?**	**Average Level for ABET:**

Table 6. Gate 4 (Critical Design Review) Rubric

The final teams work is assessed in Gate 5 (Final Presentations) and in Gate 6 (Final Technical Report). In either milestone, the teams' work is assessed by looking at the final system detailed design, the testing plans, the way the tests were conducted, the analysis of the results, the bill of materials and presentation skills. When the final projects are presented in Gate 5, the students receive feedback to add final modifications and improvements to their projects before submitting the final technical reports. Rubrics of success for Gate 5 and Gate 6 are shown in Tables 7 and 8, respectively. The final technical report represents the final document or report submitted by the teams. The teams and the projects are graded based on the technical content, the overall structure and organization of the report, the grammar and spelling, visuals and the transition from one section to another. The organization and overall structure of the report contribute to 10%; the technical content, drawings, descriptions, and necessary data to support the functionality of the product contribute to 60%; and lastly, the grammar and spelling of the whole document contribute to 30% of the total grade of Gate 6.

Name(s):		Proficient (4)	(3.5)	Emerging (3)	(2.5)	Developing	(1)	Deficient (0)	**Score (0-4)**	**x Weighting**	**Category Points**	**ABET Outcomes**
Project Title:												
Technical Content	• Did the students apply and understand technical knowledge at the baccalaureate level in order to complete the project? • Was the project at a sophistication level appropriate to a program graduate?								?	15	?	3.2 PI1 ; 3.3ORAL PI4
Lifelong Learning	• Did the student demonstrate learning beyond what is covered by the curriculum? • Were novel technologies or techniques used? • Was there evidence that sufficient research was done to affect the solution?								?	8	?	
Operation	• Considering economic constraints, does the project function as intended? • Did it meet the original specifications?								?	15	?	3.2 PI1
Testing	• Did the student provide data demonstrating that the project met (or failed to meet) specifications? • Where appropriate, were simulations performed to confirm the design? • Where appropriate, was the project calibrated against a known standard?								?	15	?	
Project Appearance	• Were ergonomics considered in the design? • Are controls labeled appropriately? • Is the prototype safe to use and robust? • For ECET were printed circuit boards used?								?	8	?	
Oral Communication	• Was the presentation organized and clear? • Did the student use proper grammar and spelling? • Was the student confident in their knowledge of the subject? • Were questions fielded in an appropriate way? • Was the presenter properly dressed (business casual or better) for a formal presentation?								?	7	?	3.3ORAL: PI2 & PI3
Graphical Communication	• Were all visual aids clear? • Were all figures graphs properly labeled and titled? • Did the presenter use appropriate units on quantities?								?	7	?	3.3ORAL: PI4 & PI5
COMMENTS:										**Total (300 max**	**?**	**3.3ORAL PI1**

Table 7. Gate 5 (Project Presentations) Rubric

4 PROJECT EXAMPLE

In this section, a project for designing and fabricating a “Thermally Controlled Bed Sheets/ Covers” [5] is presented showing the different stages discussed previously and that were followed during this Project-Based Learning course done as a capstone. The “Thermally Controlled Bed Sheets” are bed covers or sheets that people use to cover themselves with when sleeping, but are equipped with cooled and warm air to add extra comfort to the sheets to let the users enjoy a comfortable sleep while controlling the temperature of these covers. Examples of such applications found in literature review, during the market survey search for viable and existing solutions, are shown in Figure 4 (a-d).

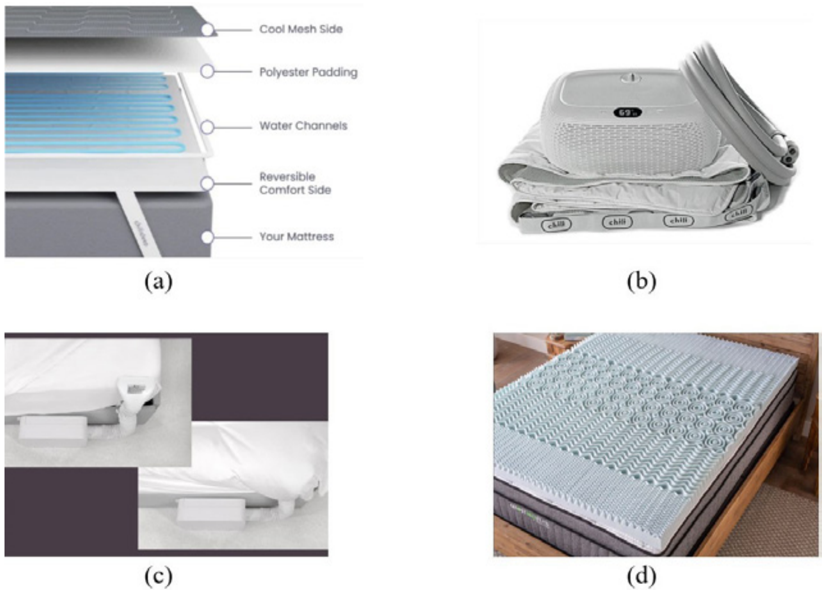

Fig. 4. Thermally controlled sheets: (a,b) embedded [6], (c) externally controlled climate comfort sleep system [7], (d) ghostbed cooling memory foam topper [8]

4.1 SURVEY

After completing the market analysis and research, the team composed a questionnaire and surveyed interested consumers. The responses are shown in Table 8.

Market Survey		
Question(s)	Results	Feedback Analysis
Do you prefer to be warm / cool when you sleep?	92.1% yes 7.9% no	There are significant number of people who refer to sleep cold
Do you have an air conditioner in your bedroom?	65.1% yes 15.9% no 19% other	Even though people had air-conditioners, they still were not sleeping cool enough
Do you sleep with white noise?	57.1% yes 28.6% no 14.3% other	Since most people sleep with noise, it would not be an issue to have some acceptable noise that can result from the design of our product
On a scale of 1-5, how comfortable do you sleep?	11.1% (5) 52.4% (4) 23.8% (3) 9.5% (2) 3.2%(1)	Most individuals who sleep with a value of 3 or less reported having "temperature cycle issues"
Would you purchase a product to help regulate the temperature of your sleeping conditions?	82.5% yes 17.5% no	
How much would you be willing to spend on a product that will provide consistently better sleep? ($100, $200, etc.)	$20-$1000	
Which of these options would you feel safe having run through your bed as you sleep?	85.7% air 14.3% fluid	Air was the safest option that people felt comfortable with
Would you use such a device for settings outside of your home (i.e. camping, hotels, visiting)	63.5% yes 36.5% no	

Table 8. Survey used in the project example [5]

4.2 SPECIFICATIONS

Based on what was shown in Figure 4 and Table 8, the system specifications were determined and are presented as follows:

- Cost: based on survey the cost of the product should be less than $300.
- Safety: the system must be safe for consumers to use. Air was decided to be used to run through the sheets instead of any fluids as preferred by the majority of surveyed participants.

- General operation: the apparatus must be user-friendly in all aspects, installation, maintenance and removal.
- Material selection: the team changed the requirement as the project progressed: during conceptual design the team proposed to use PVC pipes to carry the conditioned air through the blanket. When testing was done, it was found that there was not enough cooling when using this method; thus, the teams decided to use internal channels within the blanket.
- Environmental conditions: the apparatus must be portable and operable in all environments. The return air into the room should not contributed to significant increase in the room air temperatures.
- Time to cool: 1 °F per minute (0.56 °C per minute)
- Air flow rate: With a given duct or tube area, the speed should not cross 2 m/s
- Noise measurements: under 40 dB
- Temperature range: between 60-85 °F (16-29 °C)
- Power drawn: when the system is run directly off the house outlets, the drawn power should be no more 30 Watts when in cooling phase and no more than 200 Watts when operating at its maximum capacity.
- Battery requirements: when the system is run on DC power, the battery should be able to last for 12-14 hours before needing to recharge it. The battery must be portable and should be less than 2 pounds in weight.
- Wires resistance should be less than 1 ohms.

The system should have an interactive LCD screen showing the set temperature by the user, the measured temperature and the control status.

The following couple sections shows the progress of the project throughout the different gates discussed earlier.

Gate 1 – Proposal

The team started of the proposal with basic logic analysis as shown in Figure 5. The basic concept would be to design a unit that allows the user to enter the preferred temperature, within allowed limit that would be determined at a later stage, which would trigger the compressor of a refrigeration cycle that would cool or heat the air which would be used in turn to control the temperature of the sheets. The sheets' temperature is controlled using a sensor that would provide feedback to the expansion valve of the refrigeration cycle which in turn would increase or decrease the flow of the refrigerant to control the output from the machine. How the air would be distributed inside the blanket/sheet was not determined at this stage and as left for further discussion and brainstorming.

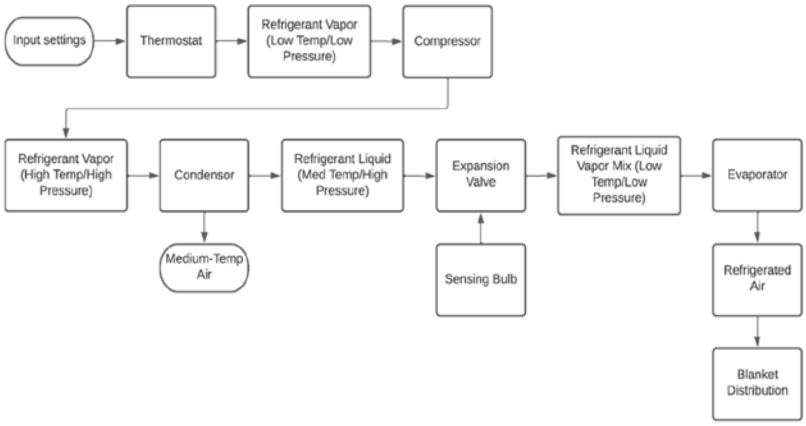

Fig. 5. Block diagram for proposed work for the "Thermally Controlled Sheets" project [5]

Gate 2 – Conceptual Design

The mechanical and electrical conceptual designs are shown in details in Figures 6 and 7.

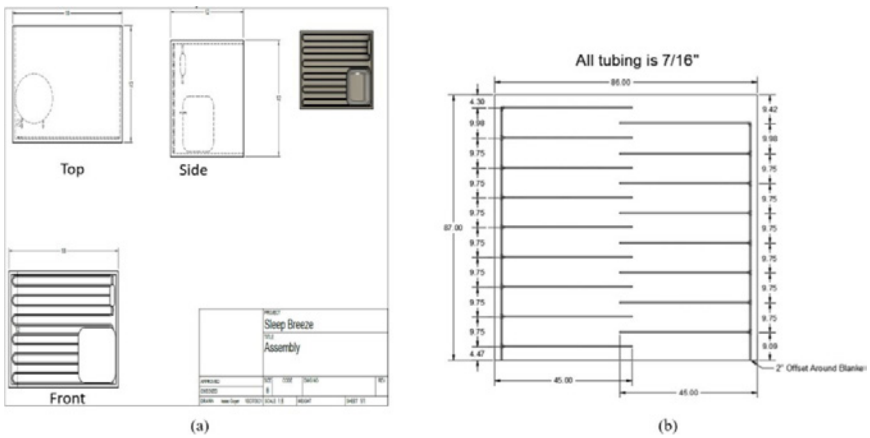

Fig. 6. Conceptual design construction (dimensions in inches) [5]

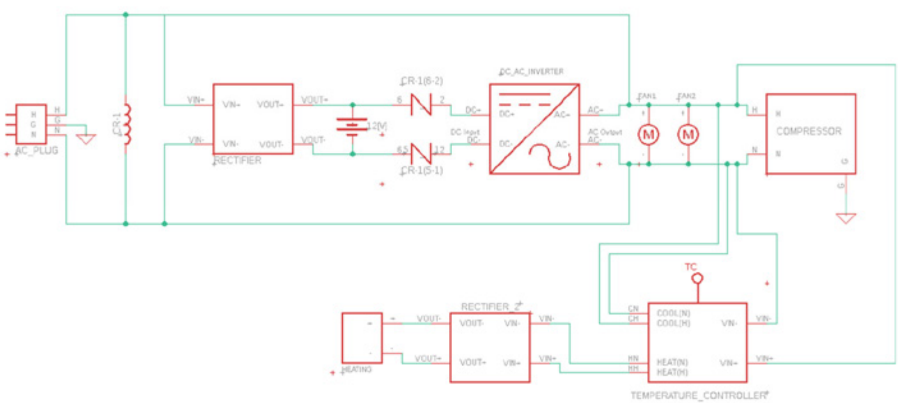

Fig. 7. Electrical details for the project during conceptual design phase [5]

Gate 3 – Prototype Demonstration.

During Gate 3 presentations, the team presented two major parts for their design: the first one was for the sheets, shown in Figure b, with the proposed PVC tubing sewed as was illustrated in Figure 6b; the second represented a prototype for the compressor, the condenser and the evaporator with the evaporator enclosed in a small wooden box that would need further improvement during the second semester.

Fig. 8. Prototype for the sheets with PVC tubing [5]

Fig. 9. Portable unit during the prototype demonstration phase [5]

Testing Procedures.

With semester starting off with main changes in the Gantt chart and the project schedule, the teams focused on designing the final product while testing each specification requirement defined earlier. The results of testing with Pass, Fail and In-progress mark are presented in Table 9.

Testing Specifications	Pass	Fail	Test in Progress
Cooling Rate (1[°F/min] (0.56 °C/min)			X
Air Flow Rate (2 [m/s] or above)	X		
Noise (under 40 [dB])		X	
Power Draw with Load (under 200 [W])	X		
Power Draw without Load (under 4 [W])	X		
Temperature Limit (60-85[°F] (15-29 °C))			X
Run Time Temperature Sine Limit (±5[°F] (±2.8°C)			X
Wire Resistance (<1[Ω])	X		
I/O Response (high pins 4.9-5[V], low pins 0-0.05[V])	X		
EEPROM (read/write previous value)	X		
SSR Response (Digital pin turns on AC load)	X		
LCD Response (title, set temp, measured temp, control status)	X		
ADC Temperature (physical measurement to Digital measurement has a +[1°F (0.56 °C)] accuracy)	X		

Table 9. Testing results

Gate 4 – Critical Design Review.

Some changes were recommended during the critical design phase and the modified design is shown in Figure 10, 11 and 12. Major changes were recommended for the air conditioning channels inside the blanket shifting from PCV tubing into two larger ducting, having 8-inch (203.2 mm) diameter each, with baffles to allow more heat transfer between the air and the blanket. The non-finalized blanket design is shown in Figure 10. A new enclosure box for the evaporator was 3D printed and is shown in the topright corner of Figure 11. The electrical details that were hidden along with the interactive LCD screen are shown in Figure 12.

Fig. 10. Modified design for the blanket with new ducting channels [5]

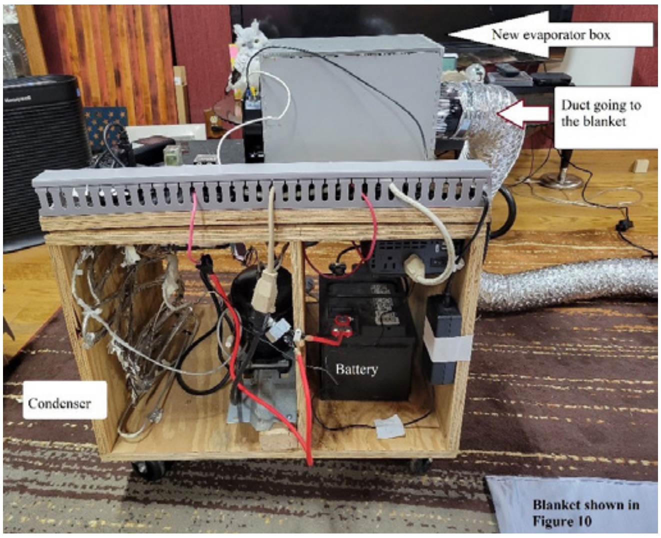

Fig. 11. Enclosure for the unit [5]

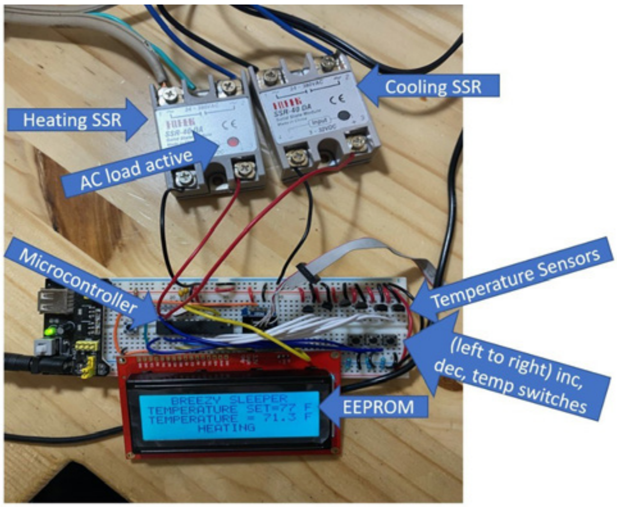

Fig. 12. Electrical components not shown in Fig. 11 [5]

Gate 5 – Final Project Presentation.

Following some changes done after the critical design feedback, the final product is shown in Figures 13 through 16. Figure 13 shows a generic isometric and side views of the air-conditioning unit, Figure 14 shows the new design from inside, Figure 15 shows the final product including the air-conditioning unit, the blanket and the flexible duct, and Figure 16 shows the final product. The main changes were that the team decided to drop out the battery option as it was only recommended to be used when going for camping, hotels, etc. However, the added weight and complexity and the availability of electricity in most camping sites and other premises, prompted the team to drop that option out. However, an optional provision was made if someone decided to run the unit on battery but the customer needs to get his own battery. Many advantages were gained due to this major shift, including lighter weight, which is almost half its weight when battery was included, and more compact portable unit (as shown in Figures 13, 15, and 16), cheaper than what it would be if battery was to be included, and a safer option, as well. An outer cover was recommended for the blanket that would go over the thermal blanket shown in Figure 15.

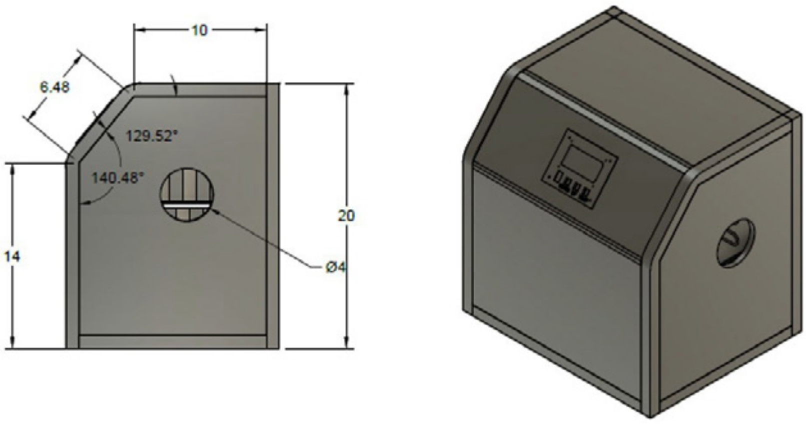

Fig. 13. Final product generic isometric and side views [5]

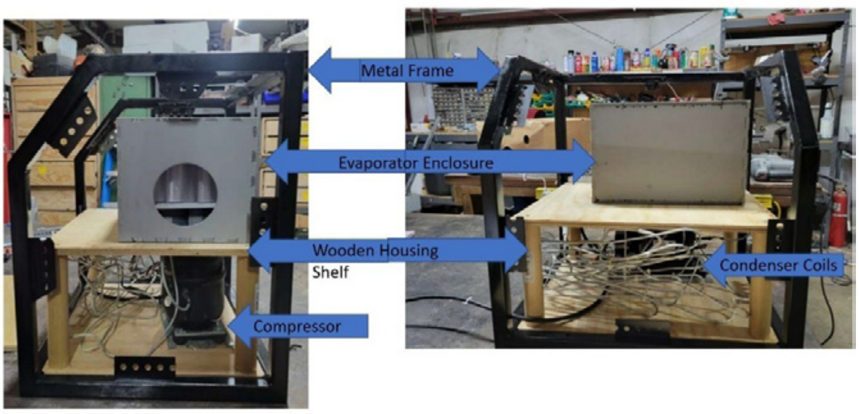

Fig. 14. Final product showing major internal components [5]

Fig. 15. Final product with enclosure over main unit and showing the thermally controlled blanket [5]

Fig. 16. Final portable air-conditioning unit showing the LCD screen and the duct that connects to the blanket [5]

4.3 ABET LEARNING OUTCOMES

There are many skills and outcomes that meet the ABET Student Outcomes using PBL technique for the capstone projects. As shown earlier in the project example, the students demonstrated concept selection and applying, tested and analyzed systems, designed and documented their analysis, and satisfied the requirements for other outcomes as shown in Table 10. Table 10 shows the general ABET Student Outcomes, the performance indicators used that defined success criteria, and the assessment methods used such as presentations, calculations, reports, etc.

	ABET Outcome	Performance Indicator #	Assessment Methods
3.1	**An ability to select and apply the knowledge, techniques, skills, and modern tools of the discipline to broadly-defined engineering technology activities**		
	Select appropriate concepts, techniques, skills and moderns tools of the discipline to participate in broadly-defined discipline specific activities	*PI-1*	Gate 1 - Problem Definition Gate 1 - Prior Art Gate 1 - Preliminary solution Gate 2 - Initial Design Concept
	Applies appropriate concepts, techniques, skills, and modern tools fo the discipline to broadly-defined discipline activities	*PI-2*	Gate 3 - Prototype Function Gate 3 - Specifications Gate 4 - Test Plan
3.2	**An ability to design systems, components, or processes for broadly-defined engineering technology problems appropriate to the discipline**		
	Awareness and understanding of a broadly defined technological problem related to a system, component, or process	*PI-1*	Gate 5 - Technical content
			Gate 5 - Operation
	Evaluation and analysis of a broadly defined technological problem related to a system, component, or process	*PI-2*	Final Report
	Design and document a creative solution to a broadly-defined technological problem	*PI-3*	Final Report
3.3ORAL	**an ability to apply written, oral, and graphical communication in both technical and non-technical environments; and an ability to identify and use appropriate technical literature**		
	Organization & Theme	*PI-1*	Gate 5 - Total Score
	Language	*PI-2*	Gate 5 - Oral Communication
	Delivery	*PI-3*	
	Supporting Material	*PI-4*	Gate 5 - Technical Content
	Visual/Graphics	*PI-5*	Gate 5 - Graphical Communication
3.3WRIT	**An ability to *apply* written, oral, and graphical communication in both technical and non-technical environments; and an ability to *identify* and *use* appropriate technical literature**		
	Context of and Purpose of Writing	*PI-1*	Final Report
	Content Development	*PI-2*	Final Report
	Convention & Mechanics	*PI-3*	Final Report
	Sources and Evidence	*PI-4*	References & Literature in Final Report
	Visuals/Graphics	*PI-5*	Final Report
3.5	**An ability to *function* effectively as a member of a technical team**		
	Contributes to Team Meetings	*PI-1*	Self-evaluation
	Individual Contributions Outside of Team Meetings	*PI-2*	
	Fosters Constructive Team Climate	*PI-3*	

Table 10. ABET Student Outcomes and assessment criteria used

5 CONCLUSIONS

Project based courses are a very powerful learning tool in preparing students to post graduation jobs. It emphasizes on many aspects needed by employers such as critical thinking, problem solving, team work and many more. This paper shows that capstone courses can be used to apply and emphasize this type of projects where students can take the responsibility of designing and implementing a complete project from brainstorming, to initial design to final steps of fabricating the product. It also emphasizes on oral and written communication skills which are all high attributes for ABET accreditation.

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OUTDOOR EDUCATION IN IRISH PRIMARY SCHOOLS (OEIPS)

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ABSTRACT

Spending time outdoors during school hours has become more popular in Irish primary schools in recent years. Not only COVID-19 has brought attention to the importance of the outdoors and the engagement with nature but research, funding and a changed mindset of teachers, have helped Irish pupils to experience a shift in pedagogy of teaching and learning regarding outdoor learning. This research will critically review the current practice of outdoor education in Irish primary schools. Specifically, the attitudes and opinions of primary school teachers as to the efficacy, the challenges and the best means of providing outdoor education in Irish primary schools, to meet curriculum outcomes, will be examined. Considering current environmental challenges, changing childhood and the need to adjust teaching pedagogies, the necessity for research of this kind, cannot be underestimated. A review of literature on the positive impact of being outdoors, teaching and learning pedagogies and experiential learning theories to understand human connections between biodiversity and climate change, is essential for children as well as for adults. This mixed-method sequential explanatory research design gives a voice to primary school teachers, training staff and relevant third parties, to discuss the importance of outdoor education in Irish primary schools and the implementation of necessary support for primary school teachers. The findings of this study will form a foundation of designing teacher training for primary school teachers, as well as continuous professional development and input into the primary school curriculum re-development in the Republic of Ireland.

Keywords: ***Outdoor Education · Primary school curriculum · Ireland · Natural environment · Experiential learning experiences · Changing childhood · Primary school teacher***

1 INTRODUCTION

1.1 INTRODUCTION TO OUTDOOR EDUCATION IN IRISH PRIMARY SCHOOLS / LITERATURE REVIEW (SLIDES 3-8)

In light of recent changes in childhood, education, climate and natural environment, it has been argued that curricula and educational pedagogies need to be redesigned to enable children to grow up with the understanding and agency to take on the challenge of dealing with the global environmental crisis and changes in children's lives in the 21st century (Wall, Litjens, & Taguma, 2015; Sirkko, Kyrönlampi, & Puroila, 2019; Haring, Sorin, & Caltabiano, 2019). These foci are mirrored through the Sustainable Development Goals (SDGs) 3 Good health and wellbeing; 4 Quality Education; 11 Sustainable cities and communities; 13 Climate action and 17 Partnership for the goals (United Nations, 2015). This demonstrates that adjusting teaching and learning pedagogies does not only affect the individual learner but focuses on a global view at the same time.

Education through and in the outdoors has become more popular and necessary in the 21st century where terms such as obesity, nature-deficit disorder, outdoor-time prescription, attention-deficit disorder, impaired social skills, or climate change can be supportive of today's view of society as a "culture of depression" as Charles et.al., (2008) explains. This provides vital ground for outdoor education to be used in primary schools as children spend more time indoors than ever before (Kellert et al., 2017).

The importance of spending time outdoors, especially in the natural environment, as well as the benefit of outdoor learning has been recognised in recent years in the Republic of Ireland. Even though the early childhood care and education sector (ECCE) has developed outdoor and risky-play years ago and development and growth are evident through Government funding, conferences, modules on outdoor and risky play in ECCE courses, CPD and many advocates from the sector. In relation to primary school education, to date, the National Council for Curriculum and Assessment (NCCA) and Department of Education (DES) have developed online webinars on the topic of outdoor learning in primary schools (NCCA, 2020; DES, 2020). This demonstrates the slow-growing interest from the Department of Education and Skills (DES), to verify the importance of outdoor learning not only in the early years sector, however, there needs to be an in-depth structure for implementation of OEIPs from a legislative side (Madden. 2019; Kelly, 2020). Regarding outdoor learning in Irish primary schools, indepth research about the state and status of nature awareness, appreciation and education in the Irish primary school system was undertaken by Madden (2019), nature education in schools had been highlighted through the work of Ni Lamhna (2009) and O'Donnell; (2017), as well as newspaper articles of benefits of learning outdoors and this not exclusively during the Covid pandemic are available (Doyle, 2019; O'Neill, 2020; Casey, 2021; Thompson, 2021). Furthermore, continuous professional development (CPD) courses on outdoor learning and nature engagement have increased since the pandemic and demonstrating links between children's learning and holistic development in the school environment.

	Outdoors	Experiential	Learning objective based	Place-based	Holistic Learning
Environmental Education					
Forest School					
Adventure Education					
Outdoor Learning					
Outdoor Education					

Present: Some elements: Not always: (Michaela Omojola, 2019)

Table 1. Outdoor learning terms identification

UNESCO (1978) defines ***Environmental Education a***s "education that helps individuals to become more knowledgeable about their environment and to develop responsible environmental behaviour and skills so that they can improve the quality of the environment" (UNESCO, 1978 p.)

Forest School is defined as "Inspirational process that offers children, young people and adults regular opportunities to achieve and develop confidence and self-esteem through hands-on learning experiences in a woodland environment" (Forest Education Initiative, 2005 p.4).

Adventure education: Ewert and Sibthrop describe adventure education as a learning process through experience in outdoor settings containing outcomes through risks and consequences (2014) that provides learning through adventure and practical experience but is not aimed on meeting primary school curriculum learning objectives. Learning and experiences are mainly focused on the individual or group.

Outdoor learning is defined as "that which is beyond the walls of the indoors" (Zink & Burrows, 2008 p. 255), which provides more memorable and stimulating learning experiences (Dillon et al., 2006; Nundy, 2001).

To understand the difference between previously explained terminologies and the used term of Outdoor Education international, the above table and the following definitions of Outdoor Educations will highlight the focus on the experiential learning element, environment, learning objective-based education and holistic learning experiences.

The Institute of Outdoor learning defines outdoor learning as "..an umbrella term for actively inclusive facilitated approaches that predominately use activities and experiences in the outdoors which lead to learning, increased health and wellbeing, and environmental awareness" (Institute of Outdoor Learning, 2020).

Centre for Outdoor Environmental Education, Linköping University (Szczepanski et. Al., 2006) defines Outdoor Education as "Outdoor education is an approach that aims to provide learning in the interplay between experience and reflection based on concrete experience in authentic situations".

Whereas ***Ford*** (1986) defines outdoor education as "...where the learning takes place (in any outdoor setting), the topic to be taught (the outdoors and any cultural aspects related to the environment), and the purpose of the activity (developing knowledge, skills, and attitudes about the world)."(Ref. p)

To focus on outdoor learning and outdoor education, the ***Institute for Outdoor Learning*** provides insight into the difference between both. "In formal settings, outdoor learning may involve education and be led by an instructor, teacher, leader or coach for an individual or group. Informally, outdoor learning happens whenever someone is experiencing the natural world and gaining knowledge, skills, understanding or appreciation."

For the purpose of this research, the term Outdoor Education is defined as "a pedagogy of teaching and learning, which takes place outdoors, through learning transfer between indoor and outdoor lessons, for the purpose of meeting curriculum outcomes and gain connectedness and care for the environment and world around us." (Omojola, 2019). This provides space and opportunities to teach whatever topic which was planned for indoors – outdoors but with the connection to a concrete environment and the world around us, which is as Bronfenbrenner states, interlinked and connected to our learning and being in his ecological systems theory (Bronfenbrenner, 1979).

1.2 FROM THEORY TO PRACTICE

Outdoor experiences from around the globe and outdoor learning have passed the stage of research and questions about their benefit and importance work children, adults, animals and the natural environment (Twohig-Bennet & Jones, 2018; Lovell, 2016; Louv, 2008; DoEH 2016, 2011; Wiedmann, Lenzen, Keyßer, & Steinberger, 2020; Ledley, Rooney-Varga & Niepold, 2017; Sjöblom & Svens, 2019). Research proves the holistic benefit and increase of health and wellbeing through outdoor learning, Irish policies have not yet included a clear voice in current documents regarding children's engagement with the natural environment (Darmody & Smyth, 2011; DES 2013; 2015; NCCA, 2017). In connection to Madden's (2019) recommendations in his research, that "Children could be brought outside for ca 15 minutes 'walkabout' a day irrespective of weather conditions to use all their senses to observe changes and views in their surroundings such as buds on trees, cloud formation, wind direction, birds etc.", to improve children's wellbeing and provide knowledge about the natural world, it is important to remember teachers heavy load of curriculum fulfilment which causes stress and provides few opportunities to include extra outdoor activities. Therefore, it is crucial to merge the current work of primary school teachers, with the outdoors, without adding extra load of resources and expectations to their work.

Recognising this importance and the reality of reduced time, availability of engagement with the natural environment and changes in childhood and education, environment and climate, there is a need to bring about change in children's daily engagement with the natural environment and vast opportunities of learning in, about and for the outdoors (Donaldson & Donaldson, 1958).

The definition of OE by Quay (2015) demonstrates an education as pedagogy to teach any subject, rather than teaching a topic. "Outdoor education as doing, as method, as process, as pedagogy that can be applied to many areas of knowledge" (Quay, 2015 p. 10). In addition to Quay's presentation of what OE is, Ford (1986) also focuses on three focus points: where, what, why. "Where the learning takes place (in any outdoor setting), the topic to be taught (the outdoors and any cultural aspects related to the environment), and the purpose of the activity (developing knowledge, skills, and attitudes about the world)" (Ford, 1986 p.1).

1.3 IN PRACTICE

The outdoor environment appears to be less structured than the common classroom environment and provides many opportunities to respond to the individual interest, needs and abilities, instead of learners responding to a set of system requirements (Rudd, 2008). Activities and noise level greatly increase in the outdoors and enables children to interact with resources physically and verbally as well as classmates (Ahamed et al., 2007; Trudeau & Shephard, 2008). This brings other learning aspects into the current task. Such a lively learning environment reminds us of Ken Robinson "A vibrant school can nourish an entire community by becoming a source of hope and creative energy......Poor schools can drain the optimism from all the students and families who depend on it by diminishing their opportunities for growth and development" (Robinson, 2015). Discussing the process, solving problems and discussing actions and plans is a vital part of outdoor education which often seems challenging in a large class and confined space. Such activities present the focus on a more learner-oriented and childinitiated approach compared to rather task-oriented activities (Waite, 2011). Therefore, outdoor education can be seen as a tool between the learner and the environment. Offering opportunities of place-based learning opportunities outdoors, which highlight the connection between human actions and their environment, can provide insight into the reality of how human actions can shape the environment we live in. This research will provide more insight into the daily practice of primary school teachers' engagement with the outdoors in their teaching and learning experiences.

1.4 INTERNATIONAL PRACTICE OF OUTDOOR EDUCATION

Considering learning in the outdoors, great development has taken place (Becker et al., 2018; Waite, 2020). In countries such as Canada, USA, Australia, Japan, Scotland, England, Germany, Austria, Switzerland and Scandinavia have already a deep and more researched experience with teaching outdoors in primary schools. With examples from Germany where the Johannes Gutenberg-University Mainz worked together with primary schools from 2013-2016, to explore the benefits for children, teachers, parents, society and the environment. Scotland does not only experience the practical implementation of outdoor learning, but Scottish primary schools have already established an outdoor learning primary school curriculum ***Curriculum for Excellence through Outdoor Learning (***CFEOL). These are positive examples to follow in the outdoor learning sector in Ireland.

1.5 HISTORY OF IRISH SCHOOL EDUCATION

Educating in the outdoors in Ireland has its roots far back as the eighteenth century, when the Hedge Schools in Dublin, Mayo, Armagh and Cork were founded (Dowling, 1935). At this time, the natural environment was not chosen for its purpose of being a 'Third Teacher' according to Reggio Emilia's socio-constructivist approach, which defines that human learning evolves through interaction with people and environment, where the elements of the environment are used to teach and learn according to Malaguzzi (1996).

With the prior developed Hedge Schools in the eighteenth century, national education has formed, after the original developed national school system which was established 1831-1872, the era of Payment by Result 1872-1900. The Belmore Commission which was established to regulate the future role of manual and practical instruction in primary education, influenced the quite narrow curriculum and called for a more child-centered movement through the Revised Program of Instruction in 1900-1922, which included reading, writing, arithmetic, geography and needlework for girls or agriculture for boys (Coolahan, 1981; Walsh, 2005). A 'new' curriculum, the Curaclam na Bunsoile, was introduced in 1971 and the foundation of a more child-centered and structured learning framework was established and seen as 'one of the major important steps on the road of educational development in this country at this time (Department of Education (DES), 1971:7). Moving on to the 1999 Primary School Curriculum, which developed through revision and re-formulation of its aims, scope and content but endorsed the underlying philosophy and principles of the 1971 curriculum, has developed into a more child-centered curriculum. The revised Language curriculum 2019, which connects both taught languages in connection, rather than as separated subjects, demonstrates the openness of cross-curricular learning. Cross-curricula learning is one of the foci of outdoor education, as various topics are connected with as many subjects as possible, to make it a more holistic learning experience. Through the changing social, economic, political and environmental world, the Irish education system implemented changes in the national curriculum and altered content and ways of teaching and learning (Lysaght, 1997; DES, 1999; Dowling, 1968; O'Malley, 2014, Murray, 2018). The Irish primary school curriculum from 1999 supports the relationship between education and society which is described as "dynamic and interactive", as it demonstrates engagement with society and the environment of pupils' lives (DES, 1999).

Walsh defines the curriculum as a "fundamental important document, which is a tool to bring about change and innovation in schools by offering new directions in terms of purpose, content, pedagogy and assessment." (2016, p.3). However, curricula are not only changed by individuals, organisations, movements and political influences, it could also be argued that school curricula ought to be the foundation of shaping children and future society as demonstrated through the SDGs (United Nation, 2015). In today's increasingly unstable, complex and unpredictable world, education can provide an opportunity to embrace this stage of change in society and the environment according to the World Economic Forum (WEF), 2020.

Engagement with one's natural environment, community life and changes in climate and biodiversity cannot successfully take place at a school desk, which is common in many Irish primary schools as a thematic review of Early Childhood Education and Care Policy in Ireland (OECD, 2004), which describes the reality of quality in infant classes in Irish primary schools as "...whole class teaching, with children sitting quietly at tables" as compare to other countries, where there is specific focus evident, on hands-on, exploratory and self-directed learning experiences, compared to table-top activities and teacher-led teaching and learning strategies (OECD, 2004, 58).

2. RESEARCH FRAMEWORK

2.1 RESEARCH QUESTIONS

The research questions evolved through the ontology and epistemology within the research topic, which sought to be answered through a specific methodology and suitable research methods. The following research questions are the foundation of the engagement with the topic of OEIP.

- To what extent does Irish primary school teachers' current practice of using outdoor experiences meet set curriculum outcomes?
- What is the current practice of planning, documenting and reviewing, outdoor learning experiences among primary school teachers of children's development?
- What are the motivations and challenges identified by Irish primary school teachers in using outdoor learning experiences to meet set curriculum outcomes?

This will address a gap in knowledge, as to date, no research has been conducted in an Irish context that specifically addresses the implementation of outdoor education through all subjects of the Irish primary school curriculum.

The originality of this research is, that there has not been any holistic study taken place, which analysed the state of outdoor education in primary schools in the Republic of Ireland. Documents which link certain primary school subjects to outdoor learning in the natural environment are available, however not a whole-school plan of linking outdoor education to the Irish primary school has been published yet. In addition, case studies of selected classes/groups have demonstrated connections between outdoor learning and children's holistic development.

2.2 AIMS AND OBJECTIVES

This research project aims to 'identify the profile of outdoor education, to meet learning outcomes of the Irish primary school curriculum' and to 'identify the current self-assessed, level of support of outdoor education, to meet learning outcomes of the Irish primary school curriculum'. The concept of Universal Design for Learning (UDL) provides a framework that can be adjusted and used for teachers as well as pupils, to ensure that, various ways of teaching and acquiring information and knowledge are provided. Furthermore, alternatives for demonstrating what is known are provided, and that learners interests are explored and challenges and increased motivation will generate new knowledge (McNutt & Craddock, 2021).

Relevant data will be collected from primary school teachers on their current outdoor experiences via quantitative and qualitative research methods. The above-defined aims are subdivided into the following four objectives. It is believed that the final analysis of collated data will help to:

1. Evaluate the current outdoor education practice of teachers practising outdoor education in Irish primary schools.

2. Gain insight into the motivations and challenges, related to incorporating outdoor learning experiences to achieve set curriculum outcomes.
3. Inform Irish policy development to further enrich children's holistic development and learning.
4. Identify best outdoor education practices in the primary school sector.

Current outdoor education practice will be investigated through the online questionnaire and semi-structured interviews. Through a sequential, explanatory, mixed-method approach, motivations and challenges to the topic will be examined. Furthermore, current relevant policies will be reviewed through the lens of the United Nations Convention of the Rights of People with Disabilities (UNCRPD), which has endorsed the Universal Design as a preferred approach to frame national policies on the design of environments, products, services and information communication technologies. This design stands as an excellent example of practical engagement with the environment for all ages and abilities and mirrors the aim of outdoor education from an universal perspective (Giulia, Ilaria & Arenghi, 2018; McNutt, & Craddock, 2021).

3 METHODOLOGY

A pragmatic-constructivist approach is used for the ontological and epistemological clarification of knowing and knowledge gain, which is demonstrated through a sequential, explanatory mixed-method, to summon the variety of aspects of this research project in a sequential manner.

3.1 PHILOSOPHICAL FRAMEWORK:

Thomas Kuhn (1962) defines the construction of a philosophical framework as a paradigm that presents a set of beliefs and how the world can be understood (Guba & Lincoln, 1994; Kivunja & Kuyini, 2017). In more detail, Gauffin and Dunlavy (2019) highlight the connections and influences of the various parts of the research background, process and connections in the following concepts inherent in a research paradigm.

3.2 RECRUITING PARTICIPANTS:

The initially decided probability sampling was identified as not the ideal form of sampling choice, as the outcome can easily be misinterpreted, as no school, location, age or qualification, clearly depicts geographic factors. Making the questionnaire available to all primary schools, offers participation without any bias, however, this uses principals and secretaries as gate-keepers, which brings the challenge along to follow up on participants (Clark, 2011).

3.3 QUANTITATIVE AND QUALITATIVE METHODS:

To capture the complexity of the study and the holistic approach to the research topic through a pragmatism-constructivist approach, it is important to use a variety of methods, which is presented through a sequential data collection approach, to gather necessary information (Palys, 1992; Creswell & Creswell, 2018). Alan Bryman (2006) argues that some, are using a qualitative method with a quantitative element to it, or vice versa, which would make one method dominant and connect a second method to the initial method. This would not represent the importance of both methods and a necessity to combine qualitative and quantitative methods as an equal and interlinked research design. Using various methods to collect measurable data and meaning of data, to construct new knowledge (Schoonenboom & Johnson, 2017).

4 ONLINE QUESTIONNAIRE

A designed online questionnaire that is guided by qualitative and quantitative methods is commonly developed through the researcher's own biases, assumptions and values, which are formed through the researcher's ontological and epistemological stances (Saunders et al., 2015).

21 questions were used to design an online questionnaire, which was sent out to all primary schools (3010 mainstream schools). The collected data to date includes 244 responses from Irish primary school teachers.

The questions of the online questionnaire were divided into groups A) geographical aspect (sex, age, location, years of experience, class allocation, school patronage, pupil size); B) outdoor learning training of teachers; C) school facilitation of outdoor learning; D) individual, school-related practice of outdoor learning in primary school; E) personal view of motivation and challenges on outdoor education.

The current data analysis is in the process of a descriptive analysis of data, from collation of the quantitative data on Microsoft Excel to report measures of central tendency, order and variation (Cresswell & Cresswell, 2018). This will take place through the three steps described by Mills and Gay (2016), which start with familiarisation with the data and identifying possible themes and connections to other data. Followed by describing the data in-depth and categorising and coding pieces of information gathered.

4.1 AN OVERVIEW OF THE RAW DATA ARE AS FOLLOWING.

Section A: geographical aspect (sex, age, location, years of experiences, class allocation, school categories, pupil size)

1. Please state your sex

2	Sex	3	Scores
4	male	5	40/16%
6	female	7	204/84%

2. Please indicate your age range

8	Age	9	Scores
10	18-24	11	8/3%
12	25-34	13	48/20%
14	35-44	15	102/42%
16	45-54	17	60/25%
18	55-64	19	24/10%
20	65 and over	21	2/1%

3. Is your school located in an

22	Location	23	Scores
24	Urban	25	83/34%
26	Suburban	27	66/27%
28	Rural	29	95/39%

4. Which category does your school belong to?

30	School categories	31	Scores
32	National school	33	203/83%
34	Multi-Denominational school	35	29/12%
36	Gaelschoil	37	14/5.7%
38	Steiner school	39	1/0.4%
40	Other	41	1/0.4%

5. How many children is your school catering for on average?

42	Number of pupils in school	43	Scores
44	less than 150 children	45	76/31.15%
46	150-250 children	47	48/19.67%
48	350-450	49	33/13.52%
50	250-350	51	30/12.30%
52	450-550	53	24/9.84%
54	more than 600	55	33/13.52%

6. How many years have you been teaching in the primary school sector?

56	Years of experiences	57	Scores
58	0-2y	59	10/3.95%
60	3-5y	61	24/9.87%
62	6-10y	63	48/19.67
64	more than 10y	65	184/75.34%

7. What class/classes do you currently teach?

66	Class distribution	67	Scores
68	Junior Infants/Senior Infants	69	47/19.26%
70	First/Second class	71	40/16.39%
72	Third/Fourth class	73	49/20.08%
74	Fifth/Six class	75	55/22.54%
76	Special Education Teacher	77	91/37.29%

Section B: outdoor learning training of teachers:

8. ***Was outdoor learning incorporated into any college courses you completed to become a primary teacher? If so, please outline how.***

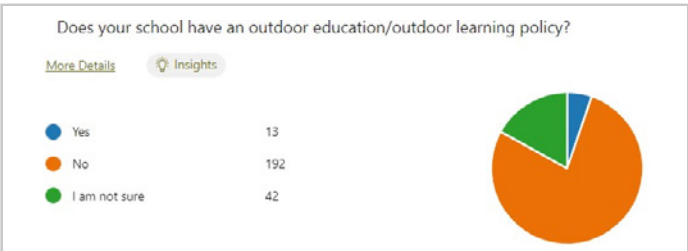
78	Outdoor learning in teacher training course	79	Scores
80	No outdoor learning in teacher training program	81	143/58.60%;
82	Some form of outdoor learning included in teacher training program	83	101/41.39%

9. ***If you have undertaken any specific training/CPD to support your outdoor education practice, please outline what training/CPD you have completed and where.***

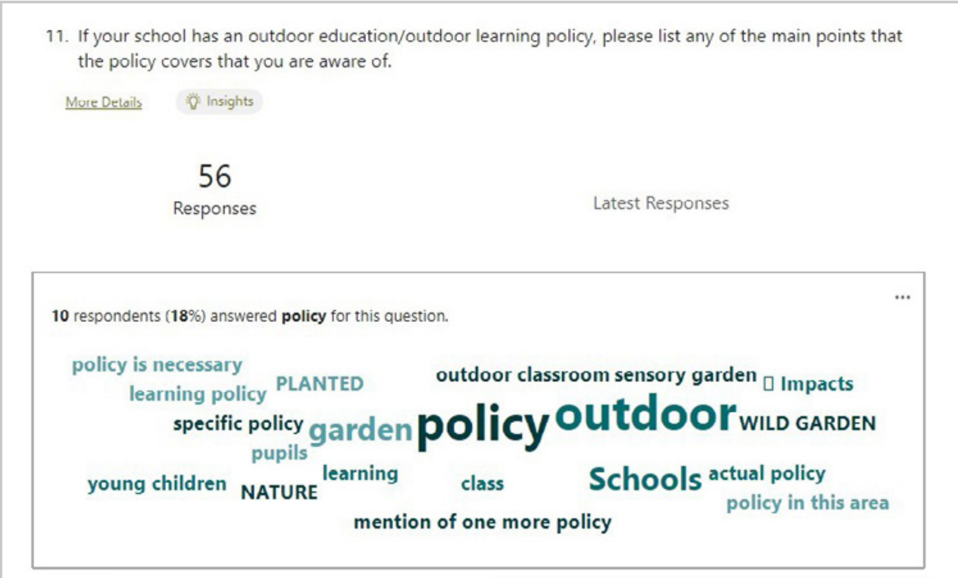
84	Continuous professional development	85	Scores
86	Yes	87	170/69.67%
88	No	89	41/16.80%
90	no response	91	33/13.52%
92	no+no response	93	30.32%

Section C: school facilitation of outdoor learning

10. Does your school have an outdoor education/outdoor learning policy?



11. If your school has an outdoor education/outdoor learning policy, please list any of the main points that the policy covers that you are aware of.

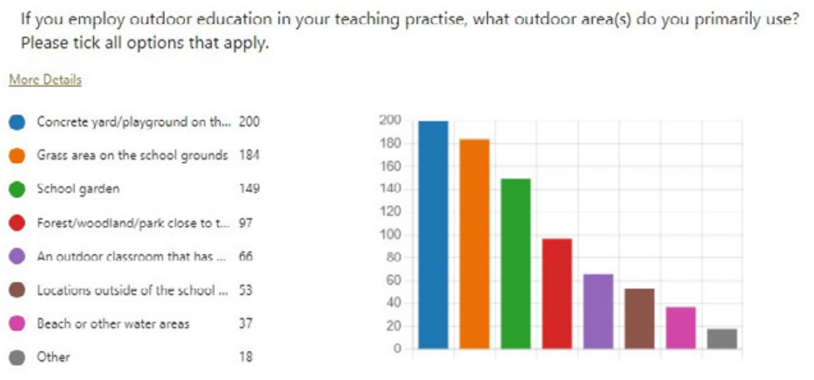


18. What supports, if any, are provided at your school to promote outdoor learning?

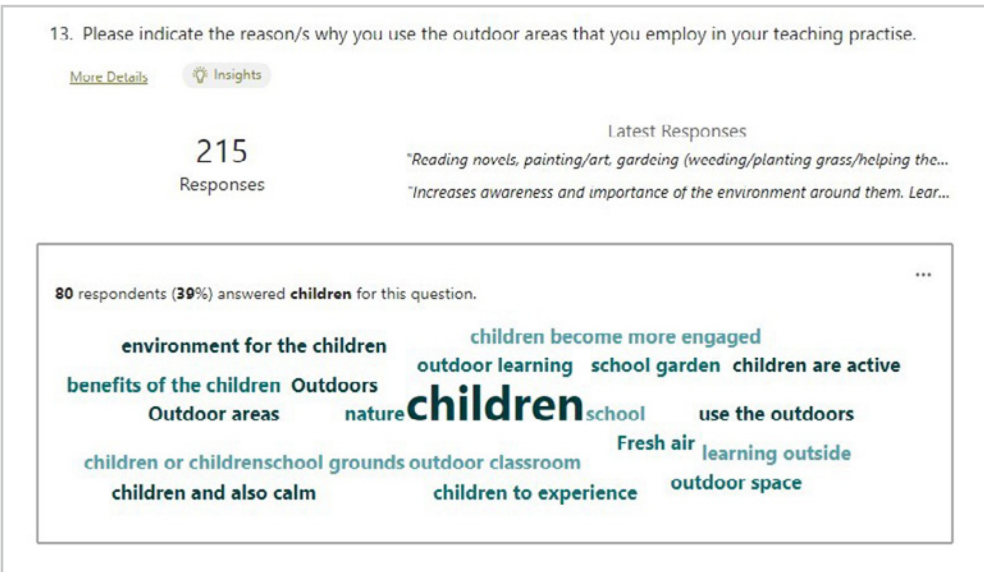
Policy on outdoor learning is not yet established in Irish primary schools but a great volume of outdoor learning activities are demonstrated here. Regarding school related support, teachers highlighted the increase of outdoor classrooms and school garden, to support their teaching and learning outdoors, especially since the recent pandemic.

Section D: individual, school related practice of outdoor learning in primary school

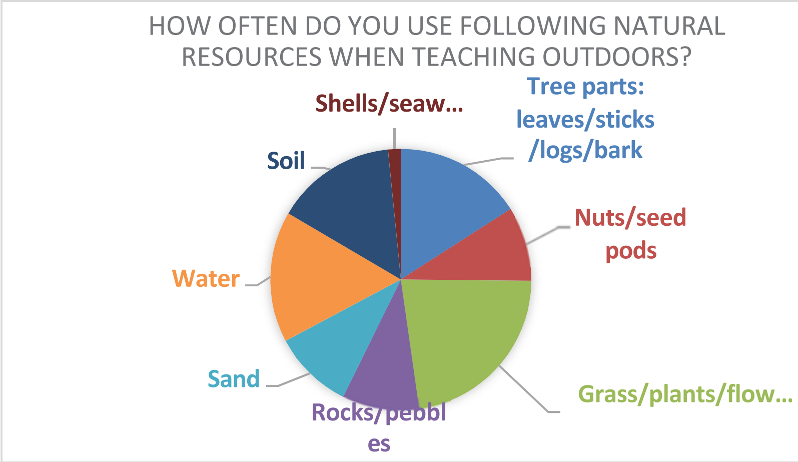
12. If you employ outdoor education in your teaching practise, what outdoor area(s) do you primarily use? Please tick all options that apply.



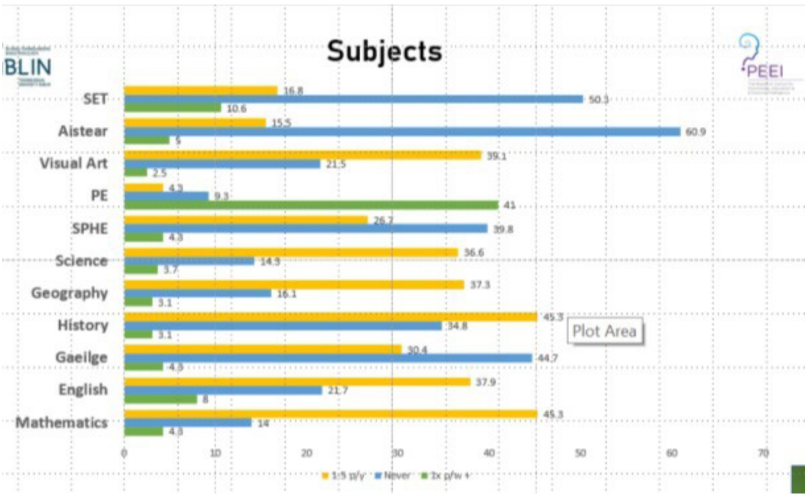
13. Please indicate the reason/s why you use the outdoor areas that you employ in your teaching practise.



14. How often do you use the following natural resources when teaching outdoors?



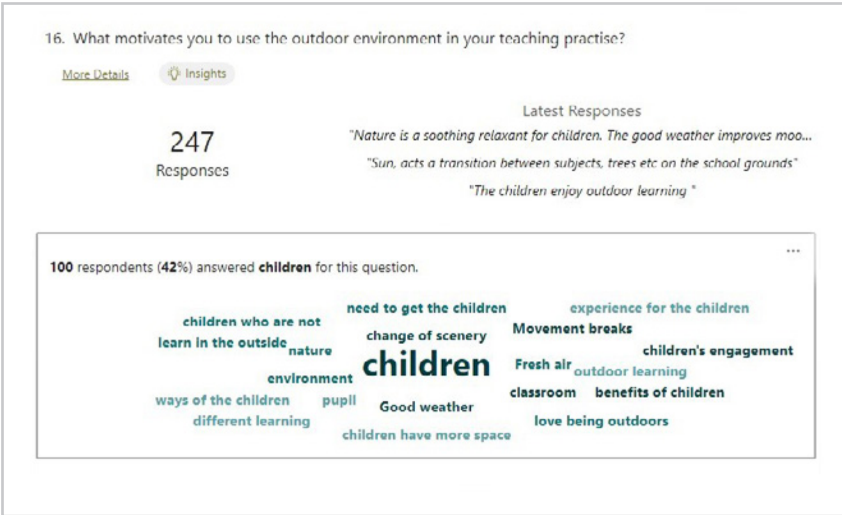
15. How often do you employ outdoor education in your teaching practise?



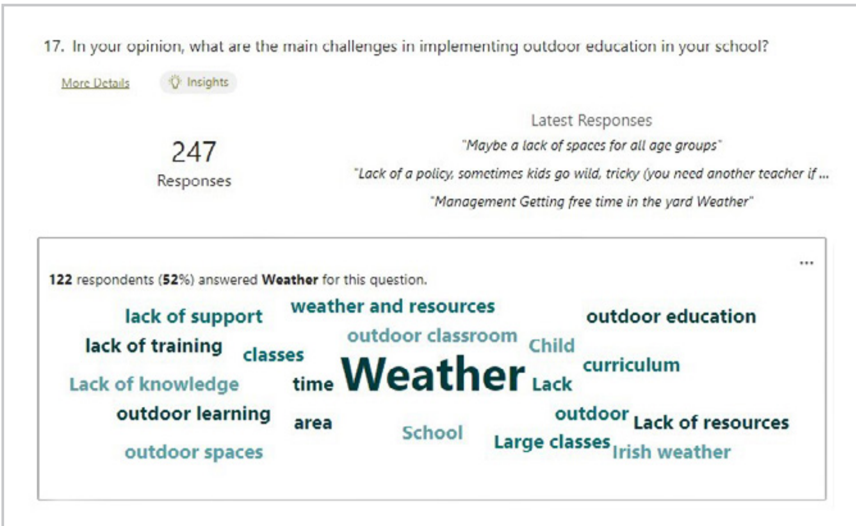
A great range of choices in resources, reason for practice outdoor learning and engagement with OE in various subjects across the whole school class-range. Discrepancies in what subjects are taught outdoors across the class levels.

Section E: personal view of motivation and challenges on outdoor education

16. What motivates you to use the outdoor environment in your teaching practise?

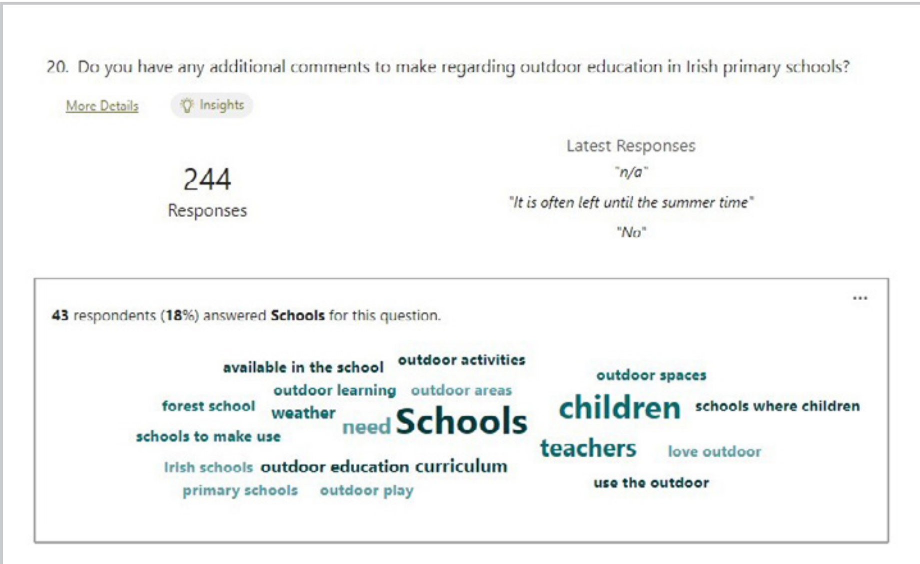


17. In your opinion, what are the main challenges in implementing outdoor education in your school?



18. Do you think, outdoor teaching and learning should be practiced more frequently in your school, if necessary support was provided?

19. Do you have any additional comments to make regarding outdoor education in Irish primary schools?



The weather is still one of the main motivator and challenge when it comes to outdoor learning experiences in Irish primary schools. Séamie Ó Néill (2020) is Head of Education and Director of School Placement in the Froebel Department of Primary and Early Childhood Education and sums up the argument about the weather. "It would appear that there is resistance in Ireland to spending time outdoors during the school day. It is fair to assume that this resistance is culturally embedded in general perceptions of 'bad' weather.

Motivational topics are health and wellbeing benefits of children and adults, connection to the natural environment, fresh air, enjoyment, hands-on learning experiences, different scenery/perspectives, space and when activities connect to the curriculum plans.

In contrast, challenges are seen in continues professional development, financial support, time and curriculum overload, classroom management, distractions, adult-child ratio, more organisation required and not enough space and resources.

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SARNETZ – TEACHING FOSSIL INDEPENDENCE OF A COMMUNITY WITH A FACT BASED, ONLINE GAME, ENGAGING GROUPS OF STUDENTS FOR INTERDISCIPLINARY TEAMWORK

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ABSTRACT

How can the energy supply of a community become more sustainable and remain affordable? "Sarnetz", an online computer game implemented by a multi-disciplinary research team from the Lucerne University of Applied Sciences and Arts, is providing possible answer. Students are competing as a team, taking on different roles, implementing measures to satisfy the objectives of a sustainable solution. In this paper, the background of the game and feedback & assessments from Swiss, Japanese, and UAE students are presented.

Key words: ***Fossil-free community • Fact-based online-simulation • Multidisciplinary teams • Multi-cultural feedback***

1 APPLIED RESEARCH

The ZERNEZ ENERGIA 2020 research project was launched in 2011 with the aim of covering the entire building-related energy requirement for a community by its own production and reducing the resulting CO_2 balance to zero. The project is composed of three research sections and a pilot building, which together should show possible ways to achieve the ambitious goals. The overall aim was to achieve fossil fuel independence for the community. In the first section, concepts for reducing building-related energy consumptions were developed. In the following section, the potential for renewable energy production in the municipal area was examined and a strategy for local energy supply was developed. The final section integrated the results of the first two sections into an overall strategy for sustainable local development [1].

Fig.1: Back-yard of pilot building "Röven 8" F

Fig.2: Front entry to Röven 8 in Zernez's center

The pilot building 'Röven 8' was selected, to demonstrate a conversion project of a typical property of Zernez from the 1870s. Sustainable local development was achieved through a combination of exemplary renovation character and the use of renewable energy production. In the interplay of energetic refurbishment measures, monument protection-compliant design and the building regulations, an exemplary handling of historical building fabric was successfully implemented here at the beginning of 2016.

2 BOARD GAME AS PART OF THE RESEARCH PROJECT

To illustrate the multi-step strategy, the research team developed the strategic board game, which was presented for the first time in 2014; initially to the high school students of Zernez and later to interested residents of the community as part of an evening information event. [2]

To strengthen the link to the actual village of Zernez, the game map is based on actual topology and property borders. The buildings are color coded: red=oil heated; yellow=district heated; white=electric heated. Historic buildings are specially marked, as their facades and roofs cannot be altered. According to the first section of the exercise, measures are marked as “renovations” to reduce the energy consumption. In addition, new buildings can be either self-sufficient or energy producing.

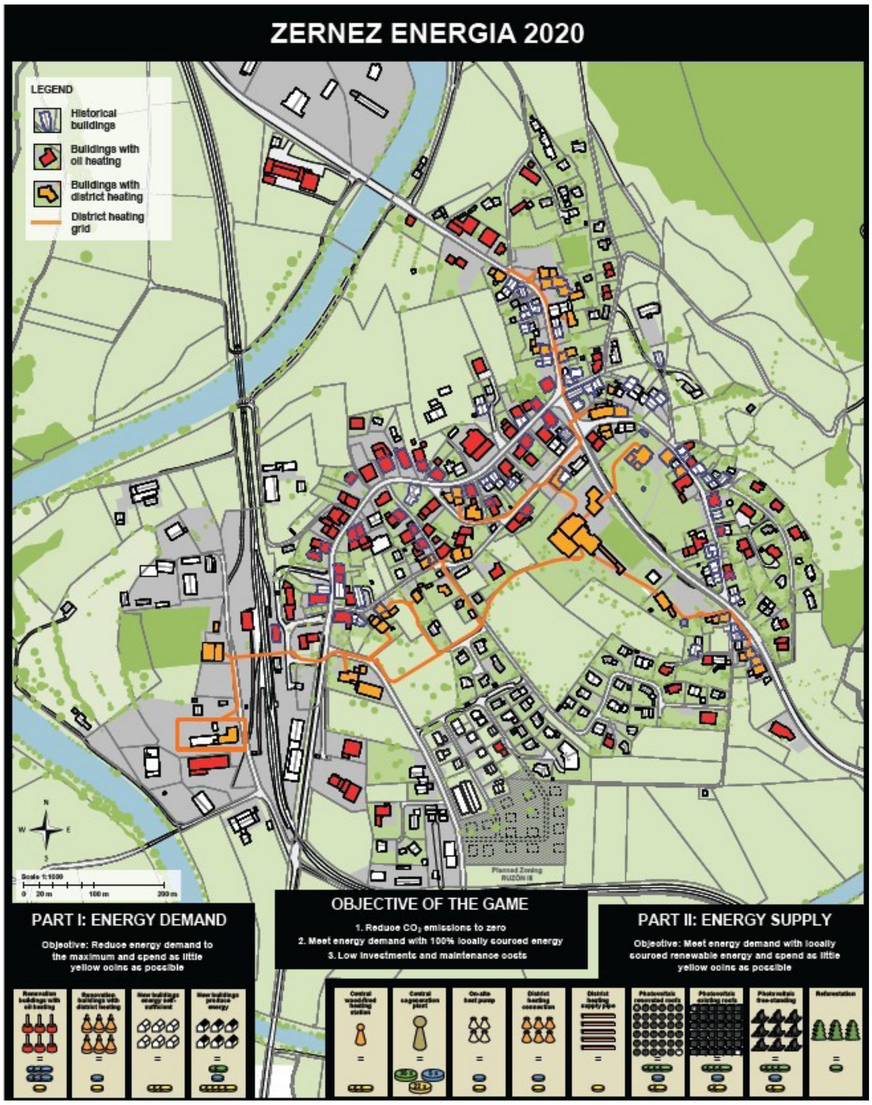

Fig.3: Translated, physical board game

According to the second section of the research project, possible measures to increase the locally produced, renewable Energy include choices of a central woodchip district heating plant or a co-generation power plant (providing electricity and heat) with the associated piping to the respective buildings and possible reforestation; options of connections to the heating grid or implementation of individual heat pumps; as well as PV for roof-mounting on non-protected buildings or free-standing on many fields.

Each of the measures results in a proportional impact on the CO2 balance, locally produced energy, and investments, represented by blue, green, and yellow coins respectively. For meeting the objective of the game to be CO2 neutral, a fixed number of 88 blue coins and to produce the required local energy, a fix number of 75 green coins need to be obtained at a minimum investment, i.e. number of yellow coins.

A team of 5 players compete to see who can create the better solution for a "carbon free" village of Zernez. During the game, each player takes on a role of a certain stakeholder, who is involved in the issues: CO2-Manager (responsible for reducing CO2 emissions), Energy-Manager (responsible for producing energy locally), Finance-Manager (responsible for keeping expenses low), Citizen Representative (arguing for the wishes of the citizens and tourist Office of Zernez) and Energy Supplier (responsible for their own interest in selling oil to Zernez). Players need to take into consideration the personal goals of their role when considering measures. Only unanimous votes are to be implemented, making the players aware that there are always compromises to be made when a plan meets the real world, which is one of the most powerful messages of the game.

3 EXPLORATION OF THE BOARD GAME

The Lucerne University of Applied Sciences and Arts has taken the board game to teach students on the interdisciplinary approach on "how to" transform a community and to make energy systems tangible. The initial target audience included not only students at the Lucerne University of Applied Sciences and Arts, but many High School Students at various institutions across German-speaking Switzerland, French speaking Geneva and Lausanne, and Italian speaking Lugano as part of the national "TecDays".

For teaching purposes, competing teams were formed and asked to present their implemented strategy to the other team and to the game master at the end of the game. It is the intention that the game is not primarily about technical issues, but rather the idea that five people with different interests and backgrounds to agree on a common strategy and a common approach to win the game together by needing the least investment. So far, no team has experienced a win without first finding this consensus. In addition, feedback is provided by the game master, complemented with questions and the presentation of the ETH-scenarios as well as the actual situation in Zernez.

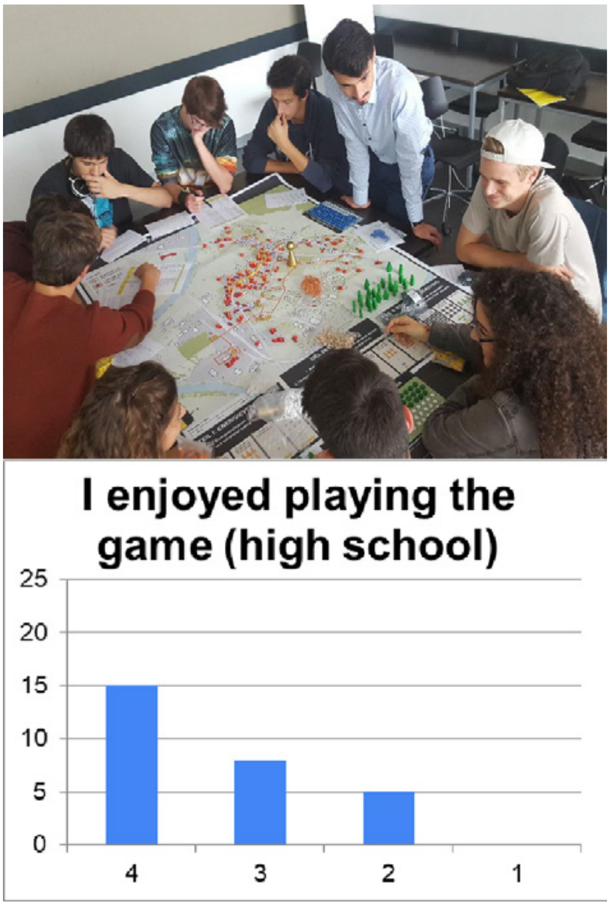

Fig.4: High School Students playing the physical board game and scoring their experience

On a scale of 1 to 4, with 4 being the best, 28 high school students rated the experience very excited (4), good (3) to acceptable (2), using statements like: "It was very interesting to see what would have to be done to create a carbon neutral community. I found it very good that we could try it ourselves and not just be shown the solution."

Internationally, the game was first exhibited at the 2017 World Expo in Kazakhstan to Engineering and to Architectural Students in Nur-Sultan (Astana) and Almaty, respectively.

Fig.5: Engineering students in Nur-Sultan (Astana)

Fig.6: Architecture students in Almaty

4 EVOLUTION INTO THE ONLINE GAME

In 2021, the Science and Technology Office Tokyo (STO) of the Swiss embassy in Japan and member of the Swissnex network, approached the Lucerne University of Applied Sciences and Arts to ask whether they could present the strategy game ZE2020 during the Summer Olympics in Tokyo in the planned Swiss pavilion. A project, however, that was slowed down by the pandemic. However, the STO-Tokyo has not given up and secured the financing for digitization and addressed interested investors with Swissnex and Presence Switzerland. Together, this example of Zernez was to be used to clearly convey Swiss approaches to CO2 reduction, to which a digital version makes an excellent contribution.

The digital version includes the actual topology and property borders within Zernez and the visual design of the buildings based on Eastern Switzerland's traditional houses. The accounting of the various measures takes place automatically and is facilitated by a moderator, as outlined in a specific paper [4].

Fig. 7: "Sarnetz" screen shut of the opening situation

The game is accessible from its own website "Sarnetz" [3]. The name was derived from the original municipality name of Zernez and the English-language «Simulation-game EneRgia2020 for CO2-NEuTral Zernez», called www.sarnetz.ch. On this website, the strategy game is presented with texts and various videos. In addition to the actual idea and the game instructions, the municipality of Zernez and its "Zernez Energia 2020" project is exhibited, as well as energy systems in general and results and news from the pioneering project.

Its online premiere took place on 21 September 2021, at the Sophia University in Tokyo. The digital game is titled "An entire CO2 neutral region?" and was also played at the Japanese Universities of Tsukuba, Osaka, Tohoku, Hiroshima and Kansai in the following days. Between October 2021 and March 2022, further events were carried out as part of the energy weeks at the world exhibition in Dubai in the United Arab Emirates.

Fig. 8: Students at Sophia University in Tokyo

Fig.9: Students from the ME at Swiss Pavilion, Dubai

5 FEEDBACK FROM STUDENTS

Students were asked to fill-out a questionnaire after the game. Responses are summarized as follow:

Fig. 10: Comparable rating by 26 Students from Japan and the UAE of the online game
(4= Strongly agree, 1= Strongly disagree)

What did you like about playing the game?

- I enjoyed stakeholder commutation very much.
- A group of people from different position and background work together as a team to develop a sustainable city.
- In the game we have to take into account a lot of factor such as gas emission, supply of energy, and scenery, so I could enjoy the process of thinking logically and developing a strategy with teammates.
- I enjoyed communicating with teammates.
- I liked how we were thinking different directions.
- I liked the graphics and the logic used for the game. In addition, I liked that there is no unified solution for the game, everyone can do it the way that he thought about it.
- The fact that's a real case and that it is challenging.
- Analyzing the problem.
- Learning about energy and waste management.
- The clear focus on the environment.

What did you learn while playing the game?

- Sustainable development need multiple stakeholders' efforts.
- It's hard to get a consensus among those people from different fields of work.
- I realized the importance of thinking from many viewpoints and compromise with others.
- I learned what people should think about to make eco-friendly city.
- Cooperation and discussion is very important.
- How to think in financial way.
- The effect of the heating system on the environment.
- How to more manage different scenarios and possibilities.
- Convincing people.
- To solve problem in smart eco-friendly ways.
- The influence of renovation for environmental improvement on other components.

The results are very promising, as to the learnings and enthusiasm, how to implement sustainable solution, by working collaboratively together. However, when it comes to the ease of use of the game itself, the results of the online game demonstrate the need to focus on the introduction and explanation of the situation:

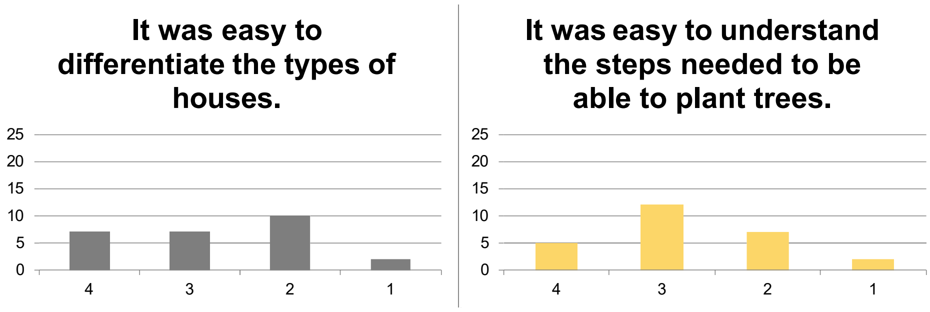

Fig. 11: Comparable rating by 26 Students from Japan and the UAE on the ease of use, (4= Strongly agree, 1= Strongly disagree)

6 OUTLOOK

The next steps include the integration of the various feedbacks – like the ease of use, and further on, an application to other regions in the world. Current projects include an assessment of the required measures to reduce CO2 emissions and to increase locally produced renewable energy in the Gulf region, where air conditioning and water desalination form the major energy requirements.

Given the importance of the building stock, it is not envisioned to include industry or mobility into this simulation, even though they make-up each a third of the energy requirement globally. Instead, this simulation is targeted towards communities, where "stationary" emissions are dominating, like in NYC.

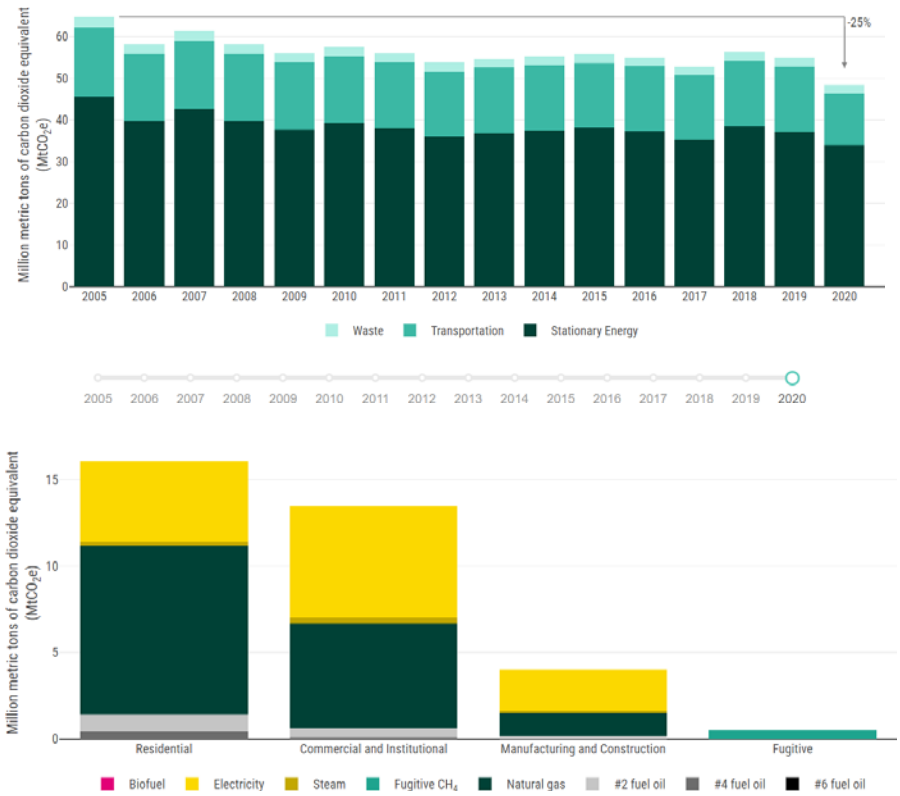

Fig. 12: New York City wide annual Green-house-gas-emissions by sector & for stationary Energy [5]

7 SITUATION IN ZERNEZ

The actual implementation of the various measures is slow, driven by the resistance of the inhabitants to invest into the renovation of the houses. Consequently, a community fund was created to allow for a complementary financial support of individual and corporate house owners. The fund is continuously fed by all electricity consumers with a contribution of 1.5 cents per kilowatt hour.

This allows the municipality, to double contributions from the canton's funding program for energy-related renovation measures and can also support targeted measures that are not considered by the canton's funding instrument. In addition, the more than 20-year-old municipal woodchip district heating plant was completely renovated, and its capacity expanded. With the planned repairs to the main street in Zernez during the next few years, the structural prerequisites will be created to connect other properties along the Via Maistra to the district heating system in the future. This is also a declared, strategic goal of the "Zernez Energia 2020" municipal commission.

Fig.13: New woodchip district heating plant

Fig.14: Renovated Building ready for connection to the district heating system

8 SUMMARY

The aim to protect the worlds environment through the elimination of fossil fuels has gained momentum. To succeed, it is increasingly recognized that the inhabitants need to be involved in any solution. This interdisciplinary approach has been applied in the village of Zernez, amid mixed results due to financial barriers. The didactic approach to teach interested groups through a collaborative tool, has proven to be very effective in terms of understanding the challenge and the need to work in interdisciplinary teams. Further work is needed to adopt the game to different communities and to the ease of use.

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5. INVENTORY OF NEW YORK CITY GREENHOUSE GAS EMISSIONS, https://nyc-ghg-inventory.cusp.nyu.edu/, April 27 Applying Authentic Assessment to Sustainability Education: A Case Study from Mechanical Engineering

APPLYING AUTHENTIC ASSESSMENT TO SUSTAINABILITY EDUCATION: A CASE STUDY FROM MECHANICAL ENGINEERING

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ABSTRACT

A core aim of Technological University Dublin is the creation of well informed and proactive graduates who will lead in creating a more sustainable future for our planet. This is in keeping with both the University's Strategic Plan and the requirements of relevant accreditation bodies such as Engineers Ireland. This paper describes an approach, funded through a competitive cross-university bursary, to make assessments more authentic for mechanical engineering students taking a second-year module on product design and CAD. The approach used to teach sustainability within the discipline is presented and the experience of practical implementation of the initiative is described.

Keywords: ***Sustainability Education, Authentic Assessment, Mechanical Engineering***

1 INTRODUCTION

A German forestry handbook introduced the word "Nachhaltigkeit" in 1713 [1]. In English, the word meant "sustained yield" and referred to the practice of harvesting just enough trees each year to ensure the forest would naturally regenerate in future years. The Bruntland Commission (formally the World Commission on Environment and Development) subsequently defined "sustainable development" as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" in 1987 [2].

Sustainability is considered one of the greatest challenges of our time and is enshrined in the seventeen Sustainable Development Goals (SDGs) unanimously adopted by all United Nations (UN) Member states in [3]. This is one of the most ambitious and important global agreements in recent history and the SDGs constitute a call for action by all countries to promote prosperity and fairness while protecting the environment and ensuring that future generations will be able to meet their needs.

Engineers are uniquely positioned in society to engage and implement the UN SDGs due to their problem-solving competences and specialized technical knowledge and a core aim of Technological University Dublin is the creation of well informed and proactive graduates who will lead in creating a more sustainable future for our planet.

Recognizing the importance of this professional bodies such as Engineers Ireland, who accredit engineering programs in Ireland, have added specific sustainability criteria to their requirements [4]. This international focus on sustainability and the emphasis on sustainability in education by professional bodies has encouraged university staff to consider the positioning of sustainability within engineering curricula. In addition, attention has been focused on how the associated assessments could be made more authentic and be more beneficial to our students.

This paper outlines an approach to integrate the teaching of sustainability into an undergraduate Product Design and CAD module for mechanical engineers. This student-centered learning approach involved significant changes to the module over the last several years and the assessment strategy used has been changed so that the deliverables approximate those that students will need to deliver once in industry. This change has been implemented in an attempt to give the students an experience to work as an engineer in a simulated environment where they can benefit from the support and feedback from the module facilitators.

2 BACKGROUND

TU Dublin is Ireland's largest university. The university offers full and part time education from micro credentials for Continuing Professional Development to trades to doctorate level. Formed from the amalgamation of three separate Institutes of Technology, it has a long history of educating students in applied engineering. There are three pillars that the new university uses as guiding principles: People, Planet and Partnership. People encompasses the intention to ignite the imagination of students. Planet is the intent to impact the planet positively through education and onward to our Partners in Industry and society.

The case study presented here focuses on a second-year module, at ordinary degree level in Mechanical Engineering, called Design and CAD. This module was originally designed to teach students the skills to develop design specifications and use current 2D and 3D software to create ISO standard drawings and specifications. In doing so students gained practical understanding and skills. The CAD element taught the lower order thinking skills as illustrated by Bloom's Taxonomy (Figure 1). While some elements were broader focused, such as use of industry standards and some higher order thinking was accessed in the design process, the opportunity to overlay the sustainability theme had been introduced using a student review of the SDG's and requiring design projects to incorporate a sustainability element.

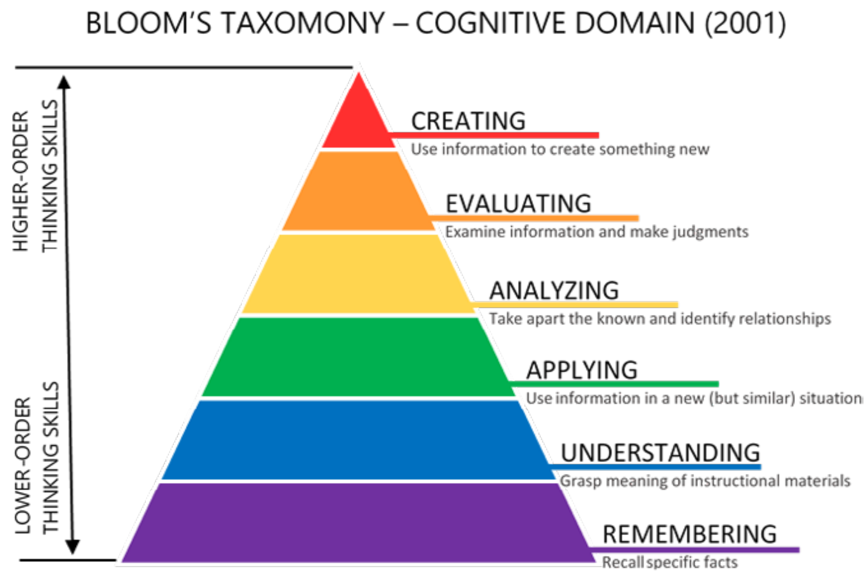

Figure 1: Blooms Taxonomy-Cognitive Domain

The existing assessment framework had developed to a point where marks were awarded for remembering (the functions of software), understanding (visualizing), applying and to some extent analyzing (reverse engineering consumer products). The higher order thinking of evaluating and creating were not introduced until a later stage of the program. It was felt that that there was scope to introduce improvements in the area of cognitive challenge (can you conceive it?), meta cognition (can you design it?), realism (can you make it?) and feedback (through reflection and group discussion).

To encourage course development the university funded a competitive bursary to be used at the discretion of the successful project leaders to progress Authentic Assessment across the university. The term “Authentic Assessment” can be interpreted in different ways. This initiative has interpreted it as “carrying out a task that requires higher level cognitive skills, collaborative working and context in approximated real-world conditions”. To achieve this the assessment must be designed to encourage students to take responsibility for their own learning. This encourages the practitioner to control the flow of information, rather than just the traditional style lecture and places the student actions at the center of class activity. This student-centered approach also encourages the student to become more reflective and aligns student learning outcomes to be more in line with their needs and the needs of industry [5]. The design of assessment should not have narrow “transactional marking” and be in line with program outcomes rather than the narrow focus of a particular module [6]. Module delivery is to be undertaken holistically within the course, and in the context of the overarching university ethos.

Design is a process that leads a student through forms of ideation, innovative focus, problem solving, and decision making and encourages higher level cognitive thinking. As part of this process prototyping is a valuable tool as examined by Nelson in his article “Opening the Black Box” [7]. In this article the value of fabricating an artefact is explored; it not only allows the designer to communicate their design intent and critical information about features, but also allows the designer to reflect on their designs and improve their understanding of complex engineering systems. The method of prototyping does not seem to be as important as the act of producing a model which provides a focus point for group members to elucidate ideas and information that may otherwise remain hidden. Prior to the implementation of this initiative the students’ focus stopped at the design stage of the process and they did not have the benefit of learning through prototyping. The project team felt that there was scope to introduce prototyping as part of the module development as illustrated schematically in Figure 2.

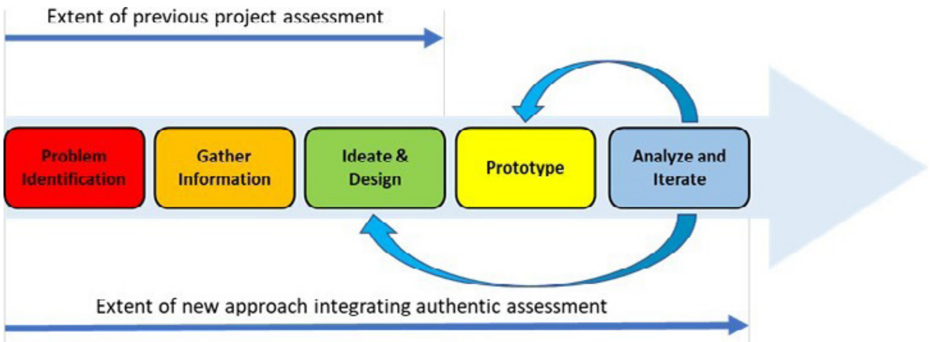

Figure 2 The Design Process

The introduction of authentic assessment into this module was made as part of an overall plan to improve the student experience and make graduates from the university more prepared for employment. As indicated in section 1, a key element of this was to prepare students for the many challenges that sustainability issues will present them with upon graduation. Section 3 explains how sustainability has been introduced into the program.

There is a difficulty in measuring the output from this process. There are positive outcomes such as increased understanding and creative ability. These skills are of high value in the areas of engineering and project management. Measuring them poses a difficulty as there is no obvious “right or wrong” answer. The Likert scale could be a useful evaluation tool, but it does not suit traditional grading schemes. In this pilot scheme, the designer’s intent, the design process and the evaluation of the prototype against these metrics seem more tangible. The success or otherwise of this trial would only be visible in the following year. Assessing this would be difficult as it posed such questions as; “are the students better prepared to complete their capstone project?”

However, there is also an opportunity to observe the development of the students over the course of a full academic year.

3 APPROACH TAKEN TO INTRODUCE SUSTAINABILITY

The Mechanical Engineering Discipline has adopted the diffusion model, sometimes referred to as the “piggybacking approach,” to explicitly integrate sustainability into the Product Design and CAD module. The approach consists of two distinct phases as shown in Figure 3. In the first students are educated about sustainability and they hear, understand and talk about sustainability and related issues. In the second phase students are educated for sustainability; to identify, define and solve problems so they can plan and implement solutions to complex sustainability issues. This is part of a bigger initiative to integrate sustainability education across all stages of the Mechanical Engineering programs.

Figure 3 Sustainability in Education

Phase 1: Educating about sustainability begins with the creation of awareness and gathering knowledge relating to sustainability. The objective is to get engineering students interested in and thinking about sustainability issues. In so doing they will be encouraged to explore their thoughts on the subject through their own experiences and develop a sustainability mindset. Learners will increase their motivation and personal confidence to consider, express and argue their own perspective on sustainability. In this phase, case studies relating to sustainability are introduced. Specific SDGs are also discussed with a particular focus on SDG 12 (Responsible Consumption and Production) in terms of the design of new products. Assessment methods vary but typically include the use of in-class discussions and multiple choice questions. Material is updated periodically to apply sustainable thinking to topical issues. This is to encourage students to think sustainably in their day to day lives and, following completion of the course, in the workplace.

Phase 2: During this phase the objective is to develop the attributes and capabilities of engineering graduates so that they can actually solve sustainability problems. Examples include creativity, opportunity recognition, decision-making by critical analysis, interpersonal and collaboration skills and the actual implementation of ideas. Open-ended activities and problems play an important role in this phase.

4 PRACTICAL IMPLEMENTATION

The Product Design and CAD module is a year-long module undertaken by students in the second year of a level 7 Mechanical Engineering Program. For the first semester students focus on developing the requisite CAD skills which they will need to develop the designs that they create in semester 2. During semester 2 the students have weekly sessions in both CAD and Product Design

As part of this initiative a review was carried out on the existing assignments and resources available to the students. The assignments for CAD involve a mixture of class work and in-class tests to assess the students' ability and are supported by a range of instructional tutorials. The task is to model a product with multiple parts and produce component and assembly drawings to ISO standards. In addition, students are introduced to the use of simulation using Finite Element Analysis. Such simulations have become common in industry and have reduced the frequency of fabricating prototypes. Designers can iterate with greater frequency without the need to engage with workshops, until designs are at an advanced stage and this is a very valuable tool for industry. However, in an educational setting it limits a student's ability to experience the processes involved and the manufacturability of the item they are designing and the revised project was designed to make this a key element of the overall student experience.

Assessments relating to Product Design consist of 2 key projects; the first of which is the reverse engineering of an everyday object on an individual basis. This teaches students to identify the various manufacturing processes and materials involved. The second related to the design of a toy or game as part of a group. The toy or game designed by the students, using a structured and systematic process, forms the focus of the rest of this paper. The initial brief given to students is shown in Figure 4

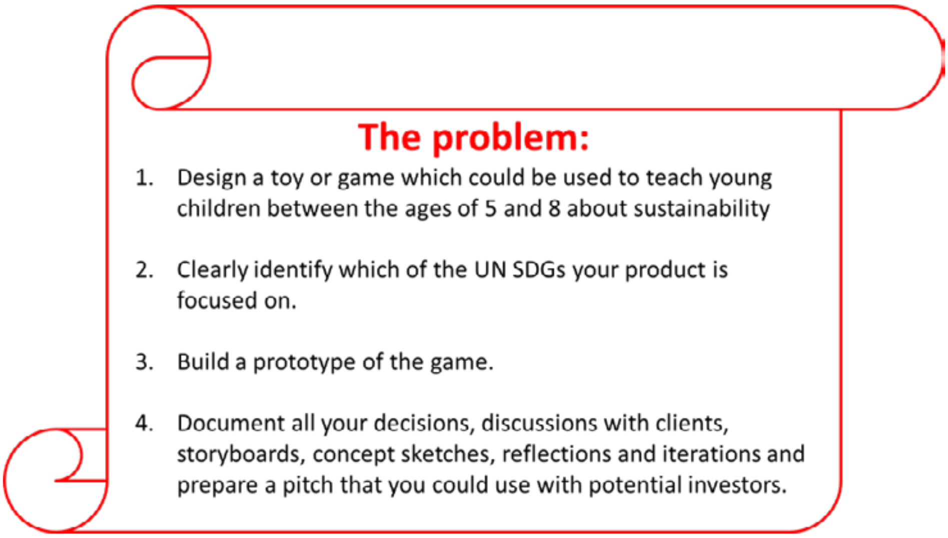

Figure 4 The Problem

This year's focus was to design and manufacture a prototype of a toy to teach children about sustainability. Students follow the design process by generating ideas as a team (brainstorming in teams, ranking ideas using basic metrics, selecting a winner), researching existing toys/games that fulfil a similar function (if any) and using the manufacturing facilities at their disposal from the college to make a basic physical prototype which models the function of the toy. The traditional design criteria (such as iterative design, sketching ideas and product design specifications) were referenced throughout the assignment brief and an extra emphasis was placed on sustainability. Students were specifically tasked with planning how to scale up their ideas for potential mass production in a sustainable way (such as in the use of bioplastics/recycled materials and using less energy intensive manufacturing processes) and to highlight the main objective of the device (to teach children about sustainability).

The module is normally carried out in two settings. Firstly, a computer laboratory for using modelling software and secondly, a classroom setting, with room for students to work collaboratively. Additional facilities to manufacture prototypes using a variety of equipment such as Fused Deposition Modelling (FDM) printers, laser cutters and plastic sheet formers were also accessible to students. Students are made aware of the availability of 3D printers, but they can use other, simple, means to produce their prototype. A time limit was imposed on the 3d printing, as this encouraged students to utilize a variety of manufacturing methods, rather than just unnecessarily and wastefully 3d printing the entire design. It also allowed for fair allocation of 3d printer access to all students if required.

Students were encouraged to make use of manufacturing facilities strictly as necessary. Lectures on additive and subtractive manufacturing were delivered to expose students to a broad selection of processes, and students were encouraged to think critically about which methods would best serve their prototype design. In practice, Students utilized 3d printing, cardboard modelling, laser cutting and hand tools to manufacture and assemble their prototypes.

The assessment grading was for following a systematic process:

- Clearly identify the sustainability element of the design
- Ideate using brainstorming
- Storyboarding
- Produce a prototype
- Evaluate the prototype and iterate as necessary to improve

Figure 5 shows an example of a storyboard demonstrating the use of renewable energy. It is a game where the child fills a tank with water. The tank releases water using gravity, which turns a water wheel, which in turn generates enough electrical energy to light the clown's nose.

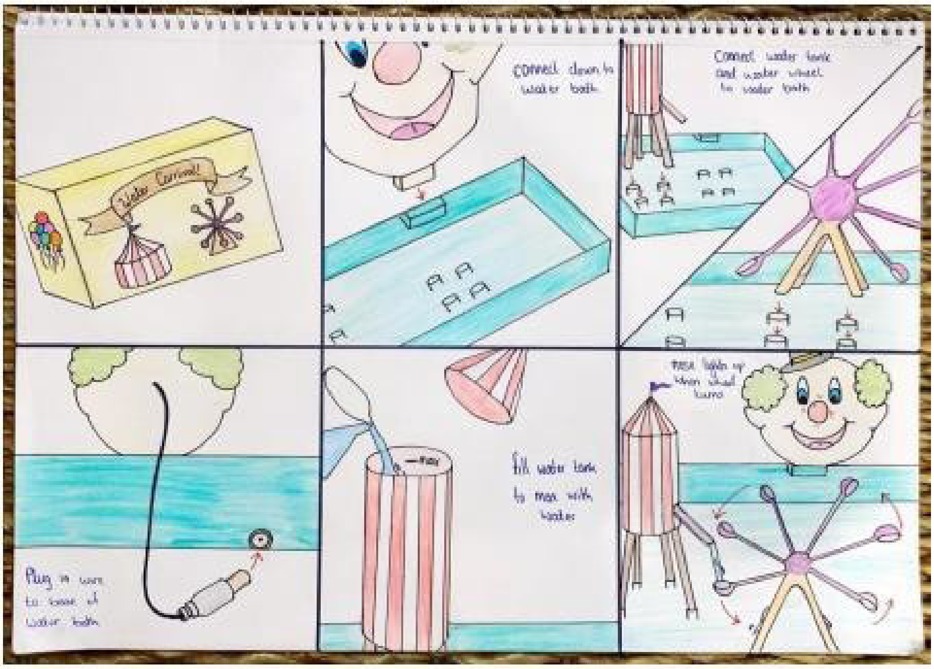

Figure 5: Example of a storyboard showing toy to demonstrate renewable energy

5 DISCUSSION OF THE EXPERIENCE TO DATE

Students are normally exposed to activities in workshops and form personal connections with their classmates. At the beginning of Semester one in September 2021, it was clear that the students had not formed these links, and this presented an additional challenge. The transition from second level to third level education involves an adjustment by students. This transition had not fully taken place with this student cohort. Discussions with colleagues confirmed this observation. However, it was felt that this made the changes more important, to help students reach the independence required of a professional engineering technician. It was difficult to successfully promote relationship building as the policy of wearing face coverings and hygiene protocols was restrictive.

Notwithstanding, the students were enthusiastic to be on campus and interacting with both the practical aspects of the course, which had previously been restricted, and the in-person interactions with staff and fellow students. As the semester progressed, the students made the adjustment and the level of participation and questioning increased.

The most significant changes were introduced in semester two. In the 3D modelling, the students were shown how to prepare a file suitable for fabrication using 3D printers. This was formatively assessed, with the students using the class to confirm their files were suitable to produce prototypes for the summative assessment in the product design part. The 3D printers were procured and assembled. In practice, there was an issue allowing students free access to them. A suitable location was not agreed and the use of the printers, unsupervised also not agreed before the assessment was due. The practical solution was to print the parts for the students and allow them to post process the items. This was to encourage reflection on the actual standard of the part, as it came off the machine and to consider how this could be altered to improve the outcome.

During the process, a collaboration with another programme was established. TU Dublin has an honors degree in Product Design. This programme uses maker spaces extensively and students carry out a lot of self-directed work. There is a proposed scheme to network printers that students can access through an app, to give them more autonomy in their work. With the agreement of the Product Design Lecturers, the intention is that both programmes will share equipment to the benefit of both sets of students. From the Mechanical Engineering point of view, this will allow for time and financial constraints to be placed on the students, to further improve the realism element of the module.

In terms of the goals as set out, to encourage higher level thinking, there were promising signs. Some of the student groups took on responsibility and fabricated their prototypes independently. Some used the facility of in-house printing. Unfortunately, some students did not manage to complete the project to produce the prototype. It is hard to gauge if these students gained from the changes. Although they may not have completed the prototype, it was observed that they had become more engaged as the process progressed. It is hoped that the benefit will come in their final year. It was also observed that although some students completed the prototyping process, the link to and importance of sustainability was not fully grasped.

Overall enthusiasm seemed to grow over the semester, with some students appreciating the nuances of the assignment. The results of the module's learning outcomes for these higher achieving students will likely be more prevalent during the final year "design and build" projects in year 3 of the program.

Pairing with the product design course for the 3d prints will allow for a more effective use of resources across the campus. It also affords students more independence around potential 3d printing, while mitigating against the risk of misuse by remotely monitoring the printers.

6 CONCLUDING REMARKS

Work is ongoing improve and develop the initiative further, by creating classroom activities that will lead the students to a better understanding of both the scope and importance of sustainability. There is room for improved access to a maker space for the students to develop improved prototypes. It is hoped that the initial prototype can be produced earlier in the module to allow additional time for reflective practice to develop.

The early signs are that the process was a success and is worth pursuing. Feedback from students would suggest that they found the task challenging at first but became more comfortable and engaged as time progressed. The assigned tasks built up to a submission that was somewhat unclear clear at the outset. Some students were uncomfortable with this open style of assessment, which did not have the usual "right or wrong" answer that is traditionally associated with technical subjects.

ACKNOWLEDGEMENTS

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THE QUALITATIVE RESEARCH ABOUT UNIVERSITY INTERNATIONAL COOPERATION TREND, PATH AND STRATEGY

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ABSTRACT

University international cooperation has become a common sense for all the university even during current pandemic. This paper is based on an exploratory survey in the form of qualitative research, aiming at finding out the university international cooperation trend, path and strategy under normalization of pandemic. The survey samples include 30 universities/institutions, and data were collected from 30 presidents, vice presidents, deans, directors, professors, officials or experts. The research results reveal four trends in university international cooperation: A first trend is that cooperative education will be stronger than that of offline long-term and shortterm exchange projects, A second trend is that online cooperation will become the norm, A third trend is the combination of online and offline cooperation model, A fourth trend will be merged international university. Based on qualitative data analysis, a need-oriented long-term cooperation strategy is concluded in the end.

Keywords: ***University International Cooperation, Trend, Path, Strategy.***

1 INTRODUCTION

University internationalization is well accepted by universities and colleges in the world, what we named university internationalization is promoting the international mobility of students and the development of university networks (Bhandari and Blumenthal, 2011), creating an attractive and competitive research and learning environment that attracts and trains high quality human resources (Vest, 2007). The European Association for International Education (EAIE) defines internationalization as the entire range of procedures by which higher education become less national, but more internationally oriented. University launches many policies and regulations to motivate staff and students to join in internationalization, develop international programs and projects to attract their participation, and adopt proper methods to ensure the university internationalization results.

Although university internationalization is well accepted by the society, the academic study about university internationalization is not that much, data of this exploratory survey is collected from presidents, vice presidents, directors, deans or senior partnership expert in the universities, senior education officers in embassies or government agencies and the research results are concluded in this paper. The exploratory survey aims at finding university ’ s prediction for international cooperation and university ’ s ideas about appropriate development paths and strategies for international cooperation, enriching research about the university international cooperation under normalization of the pandemic and helping university to overcome the obstacles during this hard period. Thus, the paper starts from introduction, followed by university international cooperation driving force, setting a clear background of the survey, and shows the results and findings through the qualitative research.

2 UNIVERSITY INTERNATIONAL COOPERATION DRIVING FORCE

In Internationalization of Higher Education, Liu Hong, Zhang Yuejin and others expounds the development strategy of Britain to internationalize higher education. They point out that the process of the internationalization of British higher education is to attract foreign students with its own economic strength, high quality of its higher education, and its own characteristics to have an impact on the world. It introduces the background of internationalization of British higher education, including the university expansion movement, the new university movement and the "unified" reform, and describes British strategies for internationalizing its higher education, (Liu Hong, 2005). Cao Wenhua and Zhong Zhenshan (2004) analyse the research perspective of Chinese scholars, and the driving force for the international development of higher education in China. The internationalization of higher education in China is inevitable in the development of economic globalization. High and new technologies, diversified educational modes and methods provide the basis for internationalization of higher education in China. After joining the World Trade Organization, China has entered the international market in terms of higher education, and universities have also been developing like an enterprise, which is conducive to the expansion of their school-running space (Cao Wenhua, Zhong Zhenshan, 2004). Chen Xuefei (2005) believes that the driving forces for internationalization of higher education include political promotion, economic drive, cultural exchanges, the laws of education, the yearning for world peace, the global dissemination of information, and international organizations advocacy. Liu Lanzhi (2002) holds that when highlighting its political and economic functions, the internationalization of higher education should not ignore individual development. The internationalization of higher education is not only a trend, but also a dynamic reflection of and positive response to the pursuit of the value of knowledge and talents in economic globalization. It should focus on the all-round development of human beings to promote the common development of human society.

The involvement of universities in countries other than their home location is a growing trend (Wildavsky, 2010; Lane, 2011; Kosmützky and Krücken, 2014; University of Oxford, 2015).The education green paper higher education: policy discussion published by the Australian government in 1987 and the education white paper higher education: policy statement published in 1988 has repeatedly stressed that instead of continuing to sponsor other countries and satisfy their education and training needs, it is better to act as a partner to pursue the common interests of the individual and the country. Since 1990, all foreign students have been required to pay full fees. The British government has taken the education of overseas students as an important part of the national development strategy, and has given strong policy and economic support to it. Both the prime minister's initiative and the prime minister's initiative on international education call for increasing the market share of international students.

Professors Altbach and Knight, in their article "internationalization of higher education: causes and realities," focus on the cross-border movement of students, programs and institutions, academics and researchers, international curricula, and the commercialization of higher education, especially the growing influence of for-profit colleges. They point out that the main motivation for universities to participate in internationalization is economic benefit. However, according to their survey results, the main motivation for traditional non-profit universities to enter the international market is not financial gain, but to improve their research and knowledge capabilities and enhance their cultural status. In the paper "push and pull factors that influence foreign students' choice of study destines", Prof. Mazarol and Sutta use the "push and pull" theory to examine the motivations for international student education. The global pattern of international student mobility is explained by the "push and pull" factors to encourage students to study abroad （Tim Mazzarol & Tim Mazzarol, 2002）. Professor Vinod Agarwal from University of Odominion and a professor at the University of Southern California, Donald R Winkler wrote foreign demand for United States higher education: a study of developing countries in the eastern hemisphere, find that the main drivers of student mobility in exporting countries are domestic per capital income, education costs, educational opportunities and the expected benefits of studying abroad (Vinod Agarwal & Donald R Winkler, 1985).

The report "costs and benefits of overseas students: from the University of Sheffield" released by school of economics, Oxford, takes the University of Sheffield as a case study to analyze the impact of overseas education on British economy from an economic perspective, analyze the cost of training foreign students and the benefits they bring to the local economy. The economic benefits of international education are clear, and are consistent with previous work by researchers such as David Greenaway (Greenaway, D., Tuck, 1995), Philip Vickers, and Bahram Bekhradnia (Phil Vickers, Bahram Bekhradnia, 2007).

Knight and Witt put forward four dimensions of motivations for internationalization of higher education: social/cultural, political, academic and economic. The first column in Table 1 lists the four dimensional drivers of Witt's 2002 update. The innovation and improvement of this kind of motivation analysis is that the third column presents a new analysis method to analyze important motivations by distinguishing them at the national and institutional levels. This motivational framework provides a detailed guide to the reasons why internationalization is training needs, it is better to act as a partner to pursue the common interests of the individual and the country.

Table 1. The internationalization motivation of higher education

Basic motivation	Current motivation	Increasingly important motivation
Society/Culture	National cultural identity Comprehension of different documents The development of citizenship Development of society and community groups	The national level: Human Resource Development Strategic alliance
Politics	Foreign policy National security Technical support Peace and mutual understanding International recognition Regional identity	Revenue generation/business development National construction/institution construction
Economics	Economic growth and competition Labor market Financial incentive	Social/cultural development and mutual understanding
Academic	Expand academic horizons Construction of colleges and universities Image and status Improve the quality International Academic Standards The international dimension of research and teaching	University level: International image and reputation Quality improvement/international standards Student and faculty development Economic income Strategic alliance Research and knowledge products

Table 1. The internationalization motivation of higher education

3 MATERIALS AND METHODS

The university international cooperation driving force provides a clear vision to understand university international cooperation. To get more details, this research, aiming at find out university international cooperation trend, path and strategy, is provided by the interviews or email survey of qualitative research and quantitative research. The sample members are the ones who have rich partnership experience, either the top management staff with great vision, like the presidents, vice presidents, or the officers in charge of policy making from the government or departments, or the senior experts with rich partnership working experience in the universities. In the exploratory survey, it is attempted to interviewee from over 50 universities or institutions, while some of them refuse the interview for different reasons, some closely guard a secret, some fail to reach as the contact has changed, some change the positions, some finish it carelessly, etc. In the end, the effective survey is 30, among which 19 collected by interviews, 7 collected by self-administered questionnaire received by e-mail, 4 collected by self administered questionnaire Wechat fill-in, the structure of the sample according to the type of institution is that 30 participants is presented in Figure 1. And there are 19 universities or government agencies surveyed by face to face dialog, 7 universities surveyed through email, and 4 universities surveyed via Wechat. The data is collected mainly from the university, while the related stakeholders of university international cooperation, governmental agency, international company, international high school and academic exchange center, are also included, to provide a more comprehensive impression.

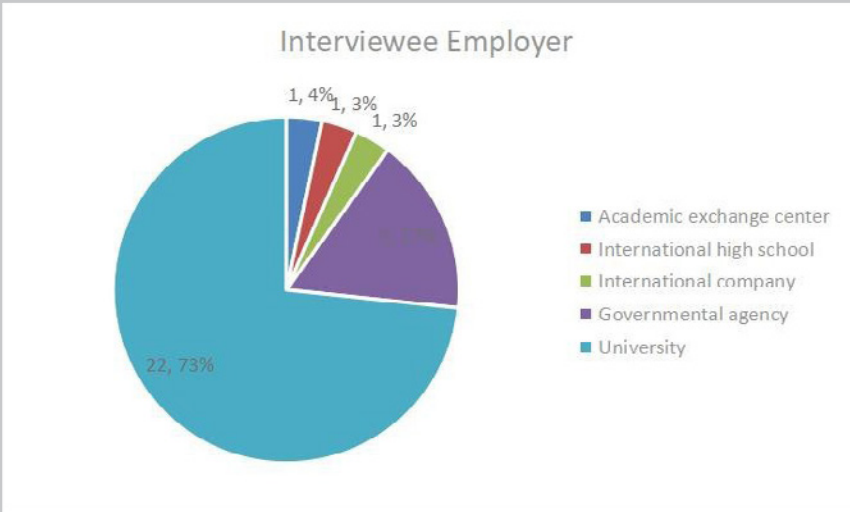

Fig. 1. The sample structure by employers of the participants.

It is noticed that the participants in the exploratory survey are the leadership of presidents and vice presidents, the management level of directors and deans, the implementation level of experts and officers, and academic level of professors (See Figure 2). Different view about university international cooperation will make the results more objective and convincing.

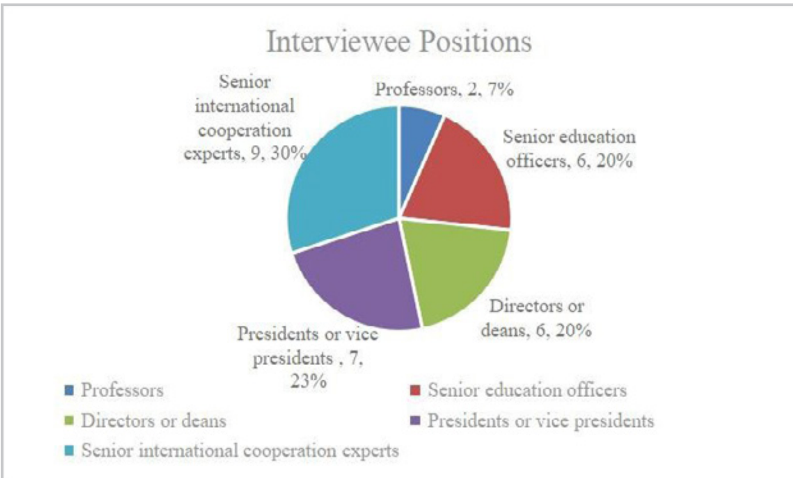

Fig.2. The sample structure by participants position.

The participants come from different countries, and among the 14 countries, they are from Asia, Europe and America, where the education system and education culture, management models are different(See Figure 3).

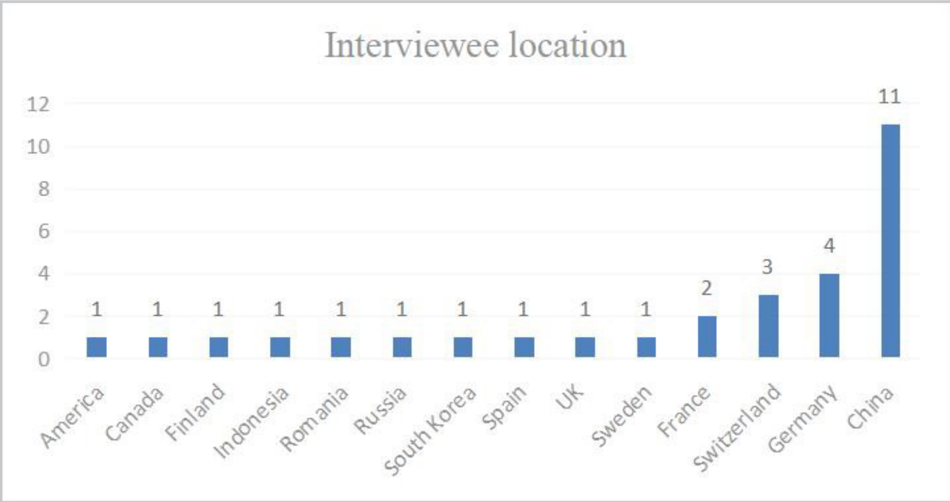

Fig.3. Number of partnership survey by interviewee location

It is known to all that university with different functions or property usually holds different views. According to the current university/institution property, the exploratory survey collects data from 15 types of universities/institutions, and the main emphasis is focused on the current main trend, comprehensive university (See Figure 4).

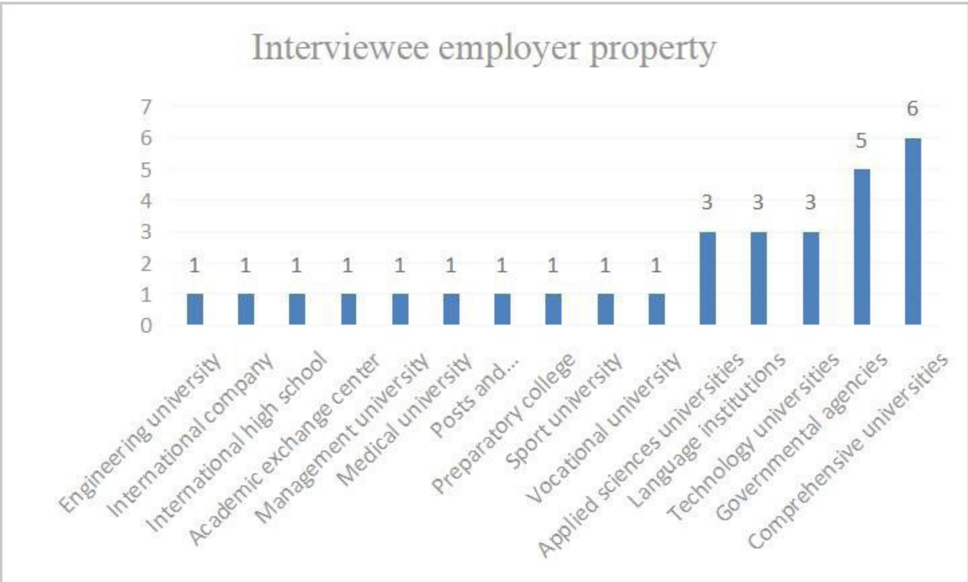

Fig. 4. Number of partnership survey by interviewee employer property

This exploratory survey is undertaken mainly in three ways: face to face, email, and Wechat, which starts from Feb. 2021 till Feb, 2022. It apparently that university staff in countries except China prefer email for survey, which usually takes around 3 to 4 weeks to receive feedback, while the university staff in China prefer to use Wechat for communication, and the survey generally takes 1 week to 2 weeks to receive feedback. For the face to face interview, some can be taken because of close contact and well relationships, and some are done in the international meetings in China or through face to face video meeting. It is found out that the email and Wechat survey can get all the answers in the interview questionnaires, while the interview can get more information beyond the interview questionnaires and can get more understanding from different aspects about behaviors of universities in establishing international partnership. The length of the interview varies, the shortest one costs 24 minutes, while the longest one takes nearly four hours.

All the answers were recorded, the content analysis was used to extract the main meaning of the answers that could be expressed by using different words. In this respect, the thematic analysis has been used. Each question is concluded, trying to find the common behaviors or regulations. The discussion formulates the exploratory survey objectives that are to find university's prediction for international cooperation and to find university's ideas about appropriate development paths and strategies for international cooperation.

4 RESULTS AND DISCUSSION

The qualitative research about the trend, path and strategy of university international cooperation is divided into two parts, the first one is the trend of international cooperation among universities in the future, which is trends prediction, and the second one is the appropriate development path and strategy for international cooperation among universities under current situations, which turns out to be the solution for the trends.

4.1 THE TREND OF INTERNATIONAL COOPERATION AMONG UNIVERSITIES IN THE FUTURE, HOW TO MAKE PREPARATIONS.

Research about the future of international cooperation among universities raises lots of researchers and practitioners ' passion, the unknown future is related to all the person involved. In the interview recording, it finds out that all the interviewees are optimistic about the future. Cooperation and exchanges are the general trend and indispensable trend of world economic integration. International cooperation of universities and colleges is an indispensable part of educational development. Internationalization could also be thought of as a university's endeavour to reach out "further afield to increase an institution's influence, visibility, and/or market share on the international scene" (Denman, 2000). The future will be great, it will have a promising future, and the trend of international cooperation is win-win cooperation, there will be more interdisciplinary international research collaboration, what is more, from the university inner demand, the demand of having international cooperation is still great and high currently because they want to increase their image, status, and accreditation,especially long term cooperation.

"What is the trend of international cooperation among universities in the future? What should we do now to make well preparation for it?", the form and contents of future international cooperation among universities are various and diversified. A first trend is that cooperative education will be stronger than that of offline long-term and short-term exchange projects, the university can extensively contact with foreign universities with similar disciplines and needs so as to carry out cooperation and expand the scope of cooperative countries and institutions. A second trend is that online cooperation will become the norm, and the hardware equipment of online teaching and communication activity should be supplemented and improved to provide a good online communication platform. A third trend will be a combination of online and offline cooperation model, at present, universities and colleges need to strengthen their own online cooperation abilities, expand the scope of online cooperation, at the same time, combined with previous offline cooperation cases, explore the combination of online and offline cooperation model, simulate the possible problems in the exploration, and actively find countermeasures. A fourth trend will be merged international universities, with the ongoing international cooperation, the need of merged international universities might also happen. The university international cooperation history tells us that there will be more and more cooperation types as the times go by.

In order to meet the future trend of international cooperation among universities, the universities should start to make preparations right now. From the interview analysis, we conclude many preparation methods, guiding what the universities should do. The first one is strategic level: correctly understand the trend and improve the strategic height, improve vision and mission where the cooperation will go further. The second one is regulations level: make system guidance, create guarantee system, carry out applicable policies, and set comprehensive regulations for international cooperation. The third one is executive level: innovate the mode of online learning, cultural exchange and scientific research exchange, and minimize the influence of wireless communication on exchange and cooperation projects; improve both the university hardware and software; improve the bilingual ability of teachers; build strong relationships with the competent partners, and build stronger commitment internally; develop the online cooperation platform, keep well communication online, and make its own strength and advantages much stronger.

The pandemic has brought changes for university international cooperation, and university leadership has explored different ways to face and solve the current obstacles, lots of sound suggestions are found in the exploratory survey.

“ The Covid-19 pandemic has shown the enhanced need for global cooperation in research, innovation, and enhancing scientific capacities. Responses to global challenges such as this will be at the heart of future international cooperation among higher education institutions. The creation of Smart University is necessary in the 4th Industrial Revolution. To cooperate with universities around the world to build smart campuses, share education facilities and teaching resources, and provide a global learning environment and opportunities for students.”—Vice president in a university, South Korea.

In order to meet the need of future cooperation, solutions comes from different angles, not only the focus but also policy are under consideration of change, and it is found that some universities have already take significant steps.

“ In my opinion, the future international cooperation will pay more attention to cultural exchanges; lead students to inquiry learning to advocate innovative development and digital science and technology development; and take the initiative to serve the social construction and globalization development. We should adjust our policies in time, keep pace with the times and actively integrate into the general environment of the international community. ” — Vice president in a university, France.

4.2 THE APPROPRIATE DEVELOPMENT PATHS AND STRATEGIES FOR INTERNATIONAL COOPERATION AMONG UNIVERSITIES UNDER CURRENT SITUATIONS

According to the American Council on Education (CIGE, 2013), establishing and managing successful collaborations and partnerships abroad are key aspects of internationalization for many institutions. The development paths and strategies for international cooperation among university are highly valued by the university leadership. Under current situations, the pandemic makes the development paths and strategies harder to decide, and the future development paths and strategies are not so clear. During this special period, the research about the appropriate development paths and strategies for university international cooperation have special meaning to university leadership, and the newest situation research will always be of great importance to enrich this blank or enhance this weak research field.

In the interview recordings,“ What do you think are the appropriate development paths and strategies for international cooperation among universities under current situations?”, it is coincident but inevitable that all the interviewees have a common sense about the appropriate development paths and strategies, which is take university need as orientation, combine the university strength and advantages, and undertake long-term valid international cooperation. To sum up the path and strategy, it is need-oriented strength based long-term cooperation.

Regarding the international cooperation need, the development path should not be stereotyped: discuss to understand the common need and find the applicable way to suit need. And it needs to serve the overall development of the university according to its own development needs, attach importance to international cooperation and development of colleges and universities, formulate development paths suitable for the university according to its situation. What is more, it should meet the development needs of the country and the university, and make the need in line with market rules. As for the competitiveness based international cooperation, under the new circumstances, it needs to give full play to university own characteristics and advantages. Do a good job in foreign affairs publicity, and expand visibility. Explore new channels of cooperation, break the barriers between the government and enterprises and public institutions with the help of government resources, carry out cooperation in various aspects, strengthen information communication, strengthen resource sharing, establish a regular exchange mechanism, step up the work of attracting talents and talents, tap and revitalize the increase and stock of foreign talents, and give full play to the multi-faceted benefits of foreign talents. Increase returns in science and technology, management and people-to-people exchanges.

With respect to long-term cooperation, there are lots of things for consideration. Firstly, establish the contact. Attend online and offline exhibition or conference, and explore from website or profiles. Find the right partners, and start from a good proposal. Find the way to get contact, and discuss in details. Find the proper partner according to your university conditions and need. Find the proper person, meet and get involved. Build cooperation upon some nice contact and make it have good cooperation at the first hand. Secondly, initiate cooperation. Sign agreement to start partnership, find mutual interests and build cooperation, and do practical programs. Thirdly, keep the cooperation working well. Build partnership starting from recognition, develop cooperative projects, maintain the cooperation long-term and make friends with partners. Sustain the current ongoing project, and make preparations for the future international partnership leap-forward development.

To manage the international cooperation, university need to improve the self education and research capability, and serving the economic development for society. " The universities should improve their own education and scientific research level, train the international comprehensive talents, and adhere to education serving economic development."—Vice president in a university, France.

The future cooperation could cover teaching, research, innovation, and under the current situations, the practical channels and virtual platform are both needed in decision consideration.

"Developing a structural, sustainable and systemic cooperation on teaching, research and innovation. Developing together virtual platforms for better and effective collaboration."— director of international office, Romania

Students, as the customers of university international cooperation, should be included in paths and strategies decision. Due to the cost performance and comprehensive talents needed in employment, the cooperative program is getting more and more popular, and has gained full support not only from the university itself, but also from the government and society.

" There is no other way to strengthen international cooperation than establishing pathway (2+2 or 3+1) program itself. This program attracts students to join because it is cheaper and practical. " —President in an institution, France.

Additionally, the cooperation direction needs to meet with the industry need, as the need is always the driving force of progress. In order to achieve that, it is better to use the university competitiveness to build a successful start of cooperation, and gradually form a solid international cooperation partnership.

" We need to find the cooperation direction according to the industry need. Then manage it with the university strength, and ensure the first time cooperation is successful. This is the right way to start a nice partnership."— Education officer in Embassy, Switzerland.

4.3 FUTURE RESEARCH DIRECTIONS

The qualitative research has already made about university international cooperation strategy. In this research, it proves a hypotheses: the appropriate development paths and strategies of university international cooperation are need-oriented strength based long-term cooperation. It is a general rule for university to follow in international cooperation, and in its implementation phase, each university should make its own need and strength analysis to formulate the most suitable plan.

As the aims of university education are educating students, the exploratory survey is followed by a quantitative research to the customer, the students, the need and demands of customers, which are indispensable, play a significant role in university international cooperation decisions. There is a special gratitude to these 30 participants in the exploratory survey who tell us university international cooperation strategy based on their professional knowledge and experience.

5 APPENDIXES

Table 2. 30 interviewee information

Organization	Organization properties	Interviewee country	Occupation
Anhui University of Technology	Technology University	China	Director of International
Dalian University of Technology	Technology University	China	Vice dean of International Education College
Dalian Medical University	Medical University	China	Dean of Public Health School
Harbin Engineering University	Engineering University	China	Senior international cooperation expert
Hebei Vocational University of Industry and Technology	Vocational University	China	Senior international cooperation expert
Nanjing University of Posts and Telecommunications	Posts and Telecommunications University	China	Senior international cooperation expert
Lanzhou University	Comprehensive university	China	Vice dean of International Cultural Exchange College
Shenyang Jianzhu University	Comprehensive university	China	Vice president
Shenyang Jianzhu University	Comprehensive university	China	Dean of Foreign Language College
Shenyang Sport University	Sport University	China	Senior international cooperation expert
Chinese Embassy in Romania	Governmental agencies	China	Senior Education Officer
University of Applied Sciences Darmstadt	Applied Sciences University	Germany	Professor
Woosong University	Management University	South Korea	Vice president
Aalto University	Technology University	Finland	Professor
INSA	Applied Sciences University	France	President (Campus de Bourges)
Transilvania University of Brașov	Comprehensive university	Romania	Director of the International Relations Office
Beijing Language & Culture Institute, Indonesia	Language Institution	Indonesia	President
St Petersburg State University	Comprehensive university	Russia	Senior international cooperation expert
Alliance Française de Perkin	Language Institution	France	President
Hochschule Wismar	Applied Sciences University	Germany	Vice president
German Academic Exchange Service (DAAD)	Academic exchange center	Germany	Senior international cooperation expert
Beijing Union University	Comprehensive university	Sweden	Course leader of international exchange program
TUVRheinland	International Company	Germany	Vice president

Table 2. 30 interviewee information

Education Department of Quebec, Canada	Governmental agencies	Canada	Senior Education Officer
U.S. Embassy	Governmental agencies	America	Senior Education Officer
Swiss International Scientific School in Dubai	High school	Switzerland	Senior international cooperation expert
Higher Education and Research in Switzerland	Comprehensive university	Switzerland	Senior international cooperation expert
Embassy of Switzerland	Governmental agencies	Switzerland	Senior Education Officer
Embassy of Spain	Governmental agencies	Spain	Senior Education Officer
Stay Campus, London, UK	Preparatory college	UK	Senior Education Officer

Table 3. The survey questionnaire

International cooperation trend, paths and strategies

9. What is the trend of international cooperation among universities in the future? What should we do now to make well preparations for it?
10. What do you think are the appropriate development paths and strategies for international cooperation among universities under current situations?

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TWO JOBS IN ONE: AN EXAMINATION OF ROOKIE TEACHER/STUDENT TEACHER EXPERIENCES

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ABSTRACT

Urban and rural school districts in Wisconsin, USA struggle with hiring teachers for career and technical education classrooms. This research examined the perceptions and experiences of student teachers hired as full-time instructors. School administrators and staff recruited students for these positions or students became aware of an opening through a state-wide job position web site. The ability to earn money while student teaching was a motivating factor for all students to accept these positions; plus, students felt they were ready to teach in their own classroom. Challenges during the experience included curriculum development and classroom management. Students' interviews suggest an individual participating in this experience must be committed to teaching as a career, have confidence in their ability to teach, and have a passion for working with both the students and the material.

Keywords. Teacher Shortage, Student Teaching, Career and Technical Education, First-Year Teacher.

1 INTRODUCTION

Teacher shortages in the United States continue to be a critical policy concern (Murnane & Steele, 2007) and the COVID-19 epidemic has exasperated the issue of teacher burnout (Pressley, 2021). Alternative education programs have sought to reduce the shortage of teachers and teacher residency programs are used in urban and rural school districts for difficult to fill teaching positions (Azar et al., 2021; Rosenburg & Miles, 2018).

A teacher residency is considered a clinical experience within a teacher preparation program, whether a traditional university program or alternative preparation program. A key component of a residency program is the support the student receives to continue and apply their learning. This typically includes fewer course preps, potentially fewer students, time to participate in collaborative planning and to observe other classrooms (Azar et al., 2021; Rosenburg & Miles, 2018). They also receive regular observations and feedback from their mentor, university supervisor, school administrator, and possibly other highly qualified instructional coaches within the school district.

Supported clinical experience has been shown to result in higher retention for both the rookie teacher and mentor/coach as their position creates a new leadership pathway for experienced teachers (Rosenburg & Miles, 2018). Further analysis of K12 students' learning also indicates

that with a resident teacher, student learning can increase from 3.5 to 4.2 months more than if they had a qualified long-term substitute or less qualified substitute teacher (Rosenburg & Miles, 2018). Other research suggests that over time, after hosting a student teacher, a mentor teacher's students have modest improvement in math and reading achievement (Goldhaber et al., 2020).

The research on residency programs shows positive results. However, residents who co-teach with a mentor teacher put a strain on school districts' limited resources, particularly at a time when the demand for teachers, especially in specialty fields, outpaces the supply.

In Wisconsin, chronic staffing shortages in the career and technical education (CTE) fields of family and consumer sciences, marketing and business education, and technology education are noted (Wisconsin Department of Public Instruction, 2016) and have led school districts to hire teacher candidates prior to them completing their student teaching. Those CTE teacher education students who have completed all the necessary requirements of a CTE teacher education program except student teaching, and have sufficient university credits to graduate, meet the hiring criteria under a Wisconsin experience-base license or a license with stipulations -Tier 1 licenses (Wisconsin Department of Public Instruction [DPI], n.d.).

If students have completed all prerequisite coursework they can complete student teaching during their first semester as a full-time teacher of record with guidance from a university supervisor and school-based cooperating teacher. Completion of this leads to a Wisconsin Tier II teaching license. This practice falls within state guidelines for licensure; however, it alters a teacher education student's supported clinical experience while still a student and places them in the position of a full-time teacher while still learning to become a teacher. Since students are hired before completing all the clinical experience in their teacher preparation program, it is unclear what impact this experience had on them and their perceptions of teaching.

2 PURPOSE OF STUDY

The purpose of this study is to examine the impact of serving as a full-time teacher, while simultaneously student teaching, on the student's experience and perceptions of teaching.

The research questions that guided this study were:

6. What is the experience of completing student teaching simultaneously as a full-time teacher in a K12 school district?
7. What supports are most beneficial to students in this situation?
8. What additional supports are needed for new teachers in similar situations?

3 SIGNIFICANCE OF THE STUDY

Given that this situation has similarities to residency programs, the results of this study could provide information that would inform program review and design of clinical placements. This study could also provide results that the UW-Stout School of Education could use to inform education students and school districts about student teaching while simultaneously teaching full time and the impact it has on the new teacher's perceptions of teaching. Lastly, there is the potential to learn about the supports within this type of model that are beneficial to student teachers success.

4 SAMPLE

The coordinator of student teacher placement was contacted and identified students who met the study criteria of student teaching while hired as a full-time teacher in the Fall semester of 2021. The coordinator supplied the names and email addresses of the students. Twelve students met the criteria, 3 male and 9 female students.

5 METHODOLOGY

After receiving approval from UW-Stout Institution Review Board, an email was sent to students asking them to complete a short researcher developed on-line survey (eight questions) using Qualtrics software. The survey asked participants to share how they learned about the position, why they chose this option, their classroom and other non-teaching responsibilities, and their demographic information. The survey also asked respondents to email if they wanted to participate in a follow-up interview with one of the researchers. A researcher developed interview guide provided consistency for the interviews across researchers. The interview questions focused on the experience of student teaching while in a full-time position, including supports, challenges, and advice for others considering this role. The interviews were recorded with participant permission and transcribed.

6 SURVEY RESULTS

Five females and one male participated in the survey for a 50% response rate. Two of the participants were 20-23 years of age and four participants were over 40 years of age.

Three participants noted that they were contacted by a school administrator or a teacher about the full-time teaching position. The other three participants found the open positions on WECAN, the state-wide web site where open teaching positions are posted.

All participants indicated that the opportunity to earn money while student teaching was a factor in their decision to pursue the position. Three participants also indicated that they felt ready to teach on their own, two participants noted they were ready to have full-time positions, and one participant was attracted to the geographic area of the school district.

Three participants had worked with their school district to obtain an experience-based license, one participant had a license with stipulations (requiring them to complete their degree program within three semesters), and two participants had a temporary/emergency placement license.

Participants staffed a variety of teaching schedules, including: 50–55-minute class periods, a block schedule of eight classes meeting three times a week for 70 minutes, 64-minute classes in a trimester schedule, 70 minutes classes in a trimester schedule, and a 30-minute block schedule. Three participants had additional assignments including committee work, a buddy program, student organization advisor, and junior class advisor.

7 INTERVIEW FINDINGS

Three students chose to participate in the interviews. Two traditional and one non-traditional adult student teacher.

All interviewees identified that money was a factor in their decision to seek a permanent teaching position; one suggested the money was the "only way I could do it in order to maintain my bills and keep my family afloat while getting my full certification." In addition, two interviewees noted they had more independence within this situation and valued having their own classroom.

One interviewee really enjoyed this experience and compared it to their earlier teaching experience (they had not completed their first student teaching experience); this person participated in the school district's orientation for first year teachers and felt she now had more individuals to ask for assistance than just asking her cooperating teacher during her first experience. Another interviewee was "one hundred percent satisfied" with the experience and had the confidence and felt ready to teach. However, they noted one area of improvement would be better time management.

In their role as a full-time teacher one interviewee noted how their school district assigned mentor, along with, a retired teacher and other teachers in the department, were very helpful in providing resources and support. The university supervisor and program director provided them with additional guidance and support. This individual appreciated the feedback that they were doing an okay job. Another interviewee noted that students had more respect for them because the position was not seen as temporary.

Challenges identified included lack of time to prepare lessons for classes, limited curriculum available, and minimal guidance from administration on what should be included in classes. Classroom management was also a challenge in a few classes. In addition, these students acknowledged communication challenges between the university program director, university supervisor, cooperating teacher, and school district administrator.

Some items that participants thought would have been beneficial for the first teaching semester included: the opportunity to observe other classes, have someone in the building observe them and confirm they were doing a good job, or someone giving them feedback on what they could do better. In addition, getting advice from other teachers regarding the different types of students that would be in their classroom was information they would have valued. As noted above, more guidance in curriculum development and course objectives would have been helpful.

Participants provided suggestions for someone opting for this path, including "if you were questioning if you want to teach, this is not the path." One person also suggested that if someone was uncertain about their teaching, "they (students) will eat you alive and you don't have anybody to back you." Other suggestions included: "being confident and having passion for both working with the students and the material that you're going to be teaching, I think is very important. If you want to do this."

8 SUMMARY

Student teaching while in a full-time teaching position has the advantage of an individual with content background staffing a CTE classroom while providing the student teacher with financial support. In addition, the student teacher has a sense of autonomy and has other teachers as colleagues from whom they can seek feedback and advice. The participants in this study were confident of their desire to become a teacher and in their abilities to teach. They recognized this was important in being able to simultaneously teach full-time and student teach. Support from mentors, other teachers, and university faculty is important for any student teacher, and the participants in this study recognized this as well. The participants identified curriculum development and classroom management as challenges.

Unlike a traditional residency program in which students have limited teaching schedules, these student teachers taught full time and had little time for additional learning opportunities that are typical in student teaching or residency programs. The participants identified several items that would be helpful during the first semester, including the opportunity to observe other classes, more observations and feedback from building personnel, meeting with other teachers to gain a sense of the student populations, and more guidance in course objectives and curriculum development.

The students in this study had a positive experience in their first semester as teachers while also student teaching. Yet they missed out on some learning experiences that may have been beneficial. Further longitudinal research with these individuals will determine whether the experience impacted their long-term commitment to teaching.

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VIRTUAL COLLABORATION FOR LEARNERS OF GERMAN WITHIN THE EUT+ ALLIANCE: DACADU INTERKULTURELL[1]

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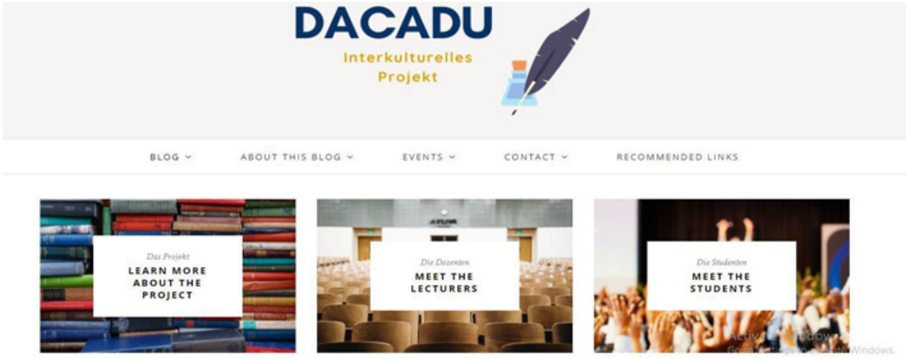
1 DaCaDu is an acronym of the names of the three participating universities. H-da Darmstadt, TU Dublin and UPCT Cartagena



PAPER OUTLINE

The aim of this paper is to provide insights into a recent virtual collaboration between staff and students at three universities in the EUt+ Alliance, TU Dublin, h-da Darmstadt and UPCT Cartagena. This paper considers the broader context of Internationalisation within the Higher Education sector, EUt+ Alliance objectives and aspirations around multilingualism and mobility and at the possibilities and limitations of virtual collaboration. We then present insights and preliminary findings from a virtual collaboration which brought together staff and students of German at three EUt+ universities, who are studying on a variety of disciplines and programmes and at various levels on the Common European Framework of Reference (CEFR).

INTERNATIONALISATION

An international dimension to Higher Education has long been recognized within Europe in both policy and practice, with institutions recognizing 'the need to reach outside the campus into the wider world, and across borders, to serve their purpose of developing effective skills among tomorrow's practitioners and decision-makers' [2]. The EU has a long history of higher education cooperation between its member states, and it increasingly involves partner countries outside Europe. Ensuring that EU higher education has a strong international dimension supports the achievement of several of the EU's internal policy objectives, notably those in education, training, employment and multilingualism. Collaboration between universities both within and beyond the EU is recognized for its capacity to 'attract talent to the EU, [ ] to promote peer learning and international comparison and [ ] to foster excellence in research and teaching. [3]

International cooperation supports innovation and job creation in the EU by enabling skill development transnationally. Study, work and training periods abroad enhance graduate employability. Graduates enjoy benefits beyond their early careers with evidence of longer term impacts on academic and career perspectives, openness to international employ-

2 https://education.ec.europa.eu/focus-topics/eea-in-the-world/european-higher-education-in-the-world

3 https://education.ec.europa.eu/focus-topics/eea-in-the-world/european-higher-education-in-the-world

ment and in terms of lifetime earnings (Engel, 2010; Iriondo, 2019). Globally, international collaborative experience and cooperation in higher education encourages future generations to think beyond national borders and is acknowledged as an effective tool in bolstering EU public diplomacy efforts and eliciting policy support. This is notably the case in areas such as international development, migration and intercultural dialogue through developing and maintaining enduring personal relationships amongst academics and graduates who along with stakeholder in society tackle common challenges. Moreover, cooperation in higher education is central to the innovation and development required to align with the United Nation's (UN) Sustainable Development Goals – especially, Goal [4]: Quality Education.[4] Many higher education projects seek to develop lifelong skills that are required to make effective progress in addressing global concerns, from improving energy efficiency to protecting the marine environment, from ensuring food security to preserving linguistic and cultural diversity.[5]

Erasmus+, the EU's flagship mobility programme, has over its 35 years, provided life-changing experiences for more than 10 million young learners and enabled over three million European students spend part of their studies at another higher education institution or with an organisation in Europe.[6] Much has been written about the value of mobility and the Erasmus experience, in particular. (Devlin, 2020; Knight, 2012; Leask, 2014). 'Erasmus+ is unique in its scope compared to the organization of international mobility in many other regions' (Devlin, 2020, 5).

New priorities for Erasmus+ include a focus on inclusion, digital education & transformation and environmental sustainability.[7] For some, the language learning and awareness aspects within a plurilinguistic Europe are central (Devlin, 2020; Jung, 2020). For others, the benefits of mobility in the development of intercultural competence and enhanced global citizenship attributes are preeminent (Schartner, 2016). Language acquisition, development and awareness are key tenets of Erasmus+, and a focus in the collaborative project described below. Jung's research (2020) highlights benefits in relation to communicative empathy, experience of multi-lingual and plurilingual spaces for exploration of linguistic repertoires, enhanced competence in mother tongue (including English) and re-evaluation of relationship with national language. Crucially too, Jung (2020) argues that 'Erasmus+ brings the geographical, geopolitical, generational, socio-economic, educational and cultural limitations of English to the fore (Jung, 2020, p. 8) Nonetheless, there are challenges and issues around mobility. Recent research points to more critical appraisal of study-abroad programmes (Vande Berg, Paige & Lou, 2012). Affordability issues raise questions about equity and student participation; there is growing competition from shorter and less expensive study visits; and internationalised curricula and whole-institution pedagogies that seek to promote cross-cultural

4 https://sdgs.un.org/goals/goal4

5 https://education.ec.europa.eu/document/commission-communication-on-a-european-strategy-for-universities

6 Erasmus+ mobility 'has positive effects on educational, social, personal and professional development, in that it enhances knowledge, skills and attitudes, improves employability, helps confidence-building and independence, stimulates curiosity and innovation, fosters the understanding of other people, and builds a sense of European belonging' https://op.europa.eu/en/publication-detail/-/publication/ff1edfdf-8bca-11eb-b85c-01aa75ed71a1/language-en

7 Erasmus+ 2021-2027 in Ireland: Possibilities & Priorities https://www.youtube.com/channel/UCBrK-UeNr4UjpiZ-7RdAqR7Q

understanding ‘at home’ (Leask, 2014). Others question the ‘Erasmus bubble’ and student motivation to engage and learn rather than travel and enjoy (Earls, 2018).

Experiences during the COVID-19 pandemic and the shift to online learning as well as growing concerns around sustainability have highlighted other challenges for mobility as a vehicle for intercultural competence development and international collaboration. They have also thrown light on potentially persuasive and viable options as substitutes, if not quite alternatives.

Leask (2014) distinguishes between product and process in internationalizing curricula. Mobility, of course, will and should continue to play a significant role, as it provides both opportunity and context for international collaboration and relationship-building in a manner that cannot be replicated if there is no physical and psychological ‘relocation’ to a less familiar cultural, linguistic, social or educational/professional setting. Attendant opportunities for skill development in adjusting to and accommodating such shifts are reduced. In defining and focusing on the means by which internationalization can be achieved, however, Leask (2009; 2014) argues that students be actively involved in the learning process, and that learning be systematic and purposeful. It is an effort, in essence, to ‘engage students with internationally informed research and cultural and linguistic diversity and purposefully develop their international and intercultural perspectives as global professionals and citizens’ (Leask 2009 in Leask, 2014, p. 3). The Da-Ca-Du project outlined below, in both its virtual component and in its planned physical mobility follow-up, is designed with such principles in mind.

1 EUROPEAN STRATEGY FOR UNIVERSITIES

In a recent European Commission communication on a European Strategy for universities, key principles and ambitions are clearly articulated.[8] The distinctive role of the universities in preserving a European way of life and in addressing challenges such as climate change & biodiversity loss and societal challenges such as digital transformation and aging populations are included. So too the central role of universities in ensuring the well-being and prosperity of future generations, in shaping resilient societies and economies, in setting the conditions and foundations for open, democratic, fair and sustainable societies to name but a few. At the crossroads of education, research, innovation, society and economy, universities play a critical role in ‘building on the cumulative asset of education systems and research networks [ ] and are ‘key actors to promote the European model in line with EU’s interests and values’. Europe needs thriving universities to ‘contribute to implementing the European Union political agenda’ [9]. The need for universities to adapt to address changing skills needs, to embed inclusion and diversity and to deliver on societal missions

8 Communication on 18 January 2022 to the European parliament, the Council, the European Economic and Social Committee and to the Committee of the Regions. https://education.ec.europa.eu/document/commission-communication-on-a-european-strategy-for-universities. The term “university” is used as a reference to the broader sector, representing the entire area of tertiary education, thus including all types of higher education institutions, including research universities, university colleges, universities of applied sciences, higher vocational education and training institutions, and higher arts institutions.

9 https://education.ec.europa.eu/document/commission-communication-on-a-european-strategy-for-universities

constitute a sound rationale for European Strategic action on universities and intensified collaboration in the HE sector. The European strategy for universities aims to support and enable 'universities to adapt to changing conditions, to thrive [ ], to join forces [ ] and to take transnational cooperation to a new level of intensity and scope and to develop a genuinely European dimension in the higher education sector, built on shared values' [10].

2 EUT+ - EUROPEAN VALUES EMPOWERING TECHNOLOGY

The European University of Technology Alliance represents one such strand of strategic activity [11]. EUt+ articulates an overarching commitment to 'European Values empowering Technology' and a discourse that constructs a narratives around a pioneering spirit, re-invention, new frontiers and a new education model to achieve openness, inclusion and cross-boundary goals [12].

For our purposes and for work on the collaborative DaCaDu project, we are most mindful of key objectives around multilingualism, language proficiency and student mobility. In the EUt+ Proposal document EPP-EUR-UNIV-2020, the following provide some relevant context: Indicators clearly articulate objectives and aspirations around multilingualism and language proficiency for students in EUt+ universities. Beginning with harmonisd programmes it is envisaged that students on such programmes demonstrate a B2 level (CEFR) on completion of Bachelor level programmes, and that Masters students also acquire a B1 (CEFR) level in a second language[13]. Further aspirations include the possibility of meetings and interactions for students and faculty in several languages.

For Common curricula and harmonised programmes, a vision is presented that maps potential directions for institutions differing in many ways with regard to their [current] educational offerings towards multi-campus delivery. The EUt+ educational experience is thus conceived to provide students and learners with practical and theoretical foundations to enable them navigate complex and evolving environments, to provide them with a fit-for-purpose qualification with which to enter the job market and with a European network of peers for whom intellectual and cultural curiosity, open-mindedness and civic values are characteristic. For students and learners, it represents an important step towards European identity.

Student mobility is also envisaged as integral to the EUt+ experience. It is acknowledged that mobility needs to financially sustainable, straightforward and pedagogically embed-

10 Under section 2. Objectives https://education.ec.europa.eu/document/commission-communication-on-a-european-strategy-for-universities,

11 https://www.univ-tech.eu/manifesto-and-identity

12 https://www.univ-tech.eu/more-european-students-will-soon-feel-at-home-on-eut-campuses; https://education.ec.europa.eu/sites/default/files/document-library-docs/european-universities-factsheet-eut.pdf

13 CEFR – Common European Framework of Reference (Council of Europe) is a framework of reference developed over 20 years of research and designed to provide a transparent, coherent and comprehensive basis for the elaboration of language syllabuses and curriculum guidelines, the design of teaching and learning materials, and the assessment of foreign language proficiency. https://www.coe.int/en/web/common-european-framework-reference-languages/table-1-cefr-3.3-common-reference-levels-global-scale

ded – in essence attractive – in order for real immersion within the partner institution and the local culture and language to be realizable. Virtual mobility is also addressed.

The DaCaDu project, as a curricular and co-curricular initiative and outlined in detail below, addresses several such objectives, and its realisation of several of these objectives and aspirations are reflected in evaluation findings and participant blog entries. As a project, DaCaDu was multi-campus, pedagogically embedded and attractive and brought together European peers for German and multilingual interaction and collaboration.

3 VIRTUAL COLLABORATION - COLLABORATIVE ONLINE INTERNATIONAL LEARNING

Higher education institutions (HEIs) around the world are presented with both challenges and opportunities brought about by globalization and advances in information, communication and internet technologies, 'forcing modern education to reflect about how to prepare students to become global citizens' (Woolf, 2010) 'while maintaining their local identities' (Woolf, 2010 & Finardi, 2014 in Júnior & Finardi, 2019, p19). The availability of effective strategies and tools to address the challenge of cultural globalization has encouraged and enabled educators to seek innovative and alternative means to prepare students and academic disciplines for the globalized world, and to deal with other systems of knowledge (Júnior & Finardi, 2019, p 20).

Virtual collaboration or mobility presents one such route to foster international academic collaboration. The term Collaborative Online International Learning (COIL) refers to an approach that aims to provide possibilities of virtual collaboration between Higher Education institutions because it can foster internationalization, particularly where financial limitations exist. Thus, our blend of COIL for the DaCaDu project could be considered as alternative, complement and precursor to academic mobility and in-person international collaboration. Coventry University's definition of COIL (Taylor, 2017) or 'virtual mobility' experiences are those 'embedded into the formal curriculum and provide students with an opportunity to interact with peers and professionals at international universities, so they can develop intercultural competences and digital skills while working together on subject-specific learning tasks or activities'[14] Key elements include the following:

1. Cross-border collaboration or interaction with people from different backgrounds and cultures.
2. Student engagement in some sort of online interaction, whether it is asynchronous or synchronous.
3. Driven by a set of internationalised learning outcomes aimed at developing global perspectives and/or fostering students' intercultural competences.
4. Reflective components that help students think critically about such interactions.[15]

14 https://www.coventry.ac.uk/study-at-coventry/student-support/enhance-your-employability/global-opportunities/collaborative-online-international-learning-coil/

15 https://www.coventry.ac.uk/study-at-coventry/student-support/enhance-your- employability/global-opportunities/collaborative-online-international-learning-coil/

Knight's definition of internationalization as 'the process of integrating an international, intercultural, or global dimension into the purpose, functions or delivery of education' (2004, p. 7), aligns with features of the DaCaDu project and provides for elaboration on a key feature, namely intercultural competence. Internationalization at Home (IaH) is sometimes used to describe the outcomes of virtual collaboration (Beelen & Jones, 2015) as it imbues curricula with added international orientations. As a strand of activity within internationalizing strategy it can reach larger cohorts of the academic community where traditional mobility may not be possible or attractive. While the authors of this paper maintain that physical mobility could and should be supported for larger cohorts of students where possible, virtual collaboration, as evidenced in the DaCaDu project, can certainly develop intercultural competence and increase understanding of and engagement with diversity, multilingualism & multiculturalism. Development of intercultural competence can be usefully defined as 'understanding not only of the culture and language being studied but also the readiness to suspend disbelief and judgment about the other culture and the willingness to reflect on one's own culture and question the values and presuppositions in one's own cultural practices.' (Chun, 2011 in Junior & Finardi, 2019, 21). It is evident in much of the DaCaDu participants' evaluative statements (sample below).

Language cannot be disassociated from culture because the forms and uses of a given language are reflections of the cultural values of the society in which the language is spoken. According to Kramsch 'we cannot be competent in the language if we do not also understand the culture that has shaped and informed it' (1993, p.23). Given the role that languages play in the construction of identities, cultures and realities, access to foreign language competency is also required through inclusive language policies to stimulate multilingualism and to counteract hegemonic forces that may position English as Lingua Franca (Finardi, Santos, Guimares, 2016; Earls, 2016). Expressive spontaneity, communicative competence and interpersonal expressiveness – over and above concerns around 'practical utilitarianism' and the more easily learned formulaic speech acts required to 'get by' – were important considerations in our pedagogical design process and its conception of intercultural competence. We subscribe to a notion of 'self construal', an important strand within scholarly literature on Intercultural Studies, as 'the degree to which people see themselves as separate from others or as connected with others' (Markus & Kitayama, 1991, 226). Self-construal may usefully be understood as 'located in the reality sui generis generated during episodes of conversational interaction, within which we express both similarity, solidarity and difference, autonomy and disaffiliation with fellow conversationalists' (Philburn, 2021, 58). The themes and activities in DaCaDu were designed to target 'conversational construal', an approach to enhance the degree to which participants could establish areas of 'overlap with each other, based not on their cultural membership or personal disposition [ ] but on their conversational contributions' and in our case, on their individual and group submissions to their co-created blog (Philburn, 2021, 58).

Finardi (2017) proposes an 'Inter-comprehension approach' and a shift away from strict monolingualism in developing intercultural competence. As an approach it recognizes that all language skills cannot or may not be learned to the same level, but it boosts internationalization with a more critical and multilingual approach. The inter-comprehension approach aims to develop linguistic awareness, focusing on the value of all languages and defending linguistic diversity as an alternative to a single language of communication. This too is evident in the DaCaDu project. Although our focus in the DaCaDu project was on German language skill development, the linguistic diversity of participants[16], their group-mediated choices for interaction in Spanish, English and German and their different levels of competence were accommodated and supported . In response to a question about languages spoken, learned or used in restricted settings, participants listed over 20 different languages. Spanish, English and German were shared languages of the participants. See Figure 1 Languages of Interaction and Figure 2 German competence levels of participants (CEFR) below.

Figure 1 Languages of interaction

Figure 2 German Competence levels of participants (CEFR)

This demonstrates what Araújo e Sá et al. (2009 in Junior & Finardi, 2019, 21) suggest are the benefits of multilingual educational projects that prepare students for the globalized world 'by evolving comprehension of different languages and establishing relationships at several linguistic levels – lexical, morphosyntactic, and phonic'. For us, the DaCaDu project also meant challenging the hegemony of English in internationalization efforts and demonstrating possibilities for multilingual educational experiences, as well as aligning our efforts with wider national languages strategy and EUt+ objectives. [17]

Our virtual and embedded blended or hybrid approach to teaching and learning enhanced

16 In response to a question about languages spoken, learned or used in restricted settings, participants listed over 20 different languages. Spanish, English and German are shared languages of the participants.

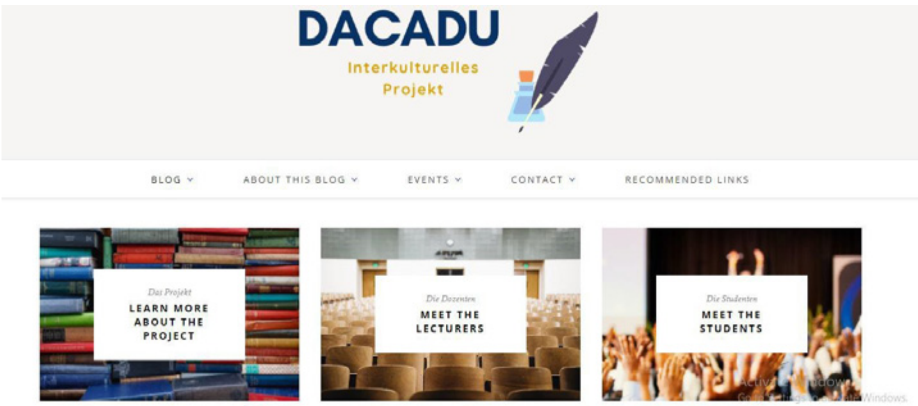
17 Ireland's long-awaited National Strategy on Foreign Languages in Education, Languages Connect for example, sets out targets for continued and enhanced high-quality language learning opportunities and competence in both of the official languages, Irish and English. Crucially, however, it sets outs new and ambitious targets around foreign language learning, citing ambition for Ireland to compete on the global stage, the need for educators and employers to work together to increase awareness of the importance of gaining proficiency in foreign languages, and setting out ambitious targets for primary, secondary and tertiary education. https://www.gov.ie/en/publication/dd328-languages-connect-irelands-strategy-for-foreign-languages-in-education-2017-2026/

face-to-face teaching and pedagogical practices and interactions. DaCaDu was delivered synchronously and asynchronously, ie. synchronously by ourselves as teachers present in real time during classes and online tutorials to promote interaction among all involved, and asynchronously, whereby the time and space of interactions were chosen and aligned with participants' needs and facilitating different time zones, academic calendars and schedules.

Such blended learning approaches have value in higher education contexts scenario due to their flexibility and they present innovative features that also enable institutions to better explore physical space and faculty time (Dziuban et al., 2006). Vygotskian sociocultural and social interaction paradigms also frame DaCaDu learners' experiences of language learning in social contexts. Through scaffolding and efforts to bridge learning gaps (such as classroom interactions, editing supports and tutorials/drop-in online Q&A sessions) students moved towards enhanced understanding and critical reflection. [18]

The DaCaDu project, as an example of collaborative online international learning combined four essential dimensions of virtual mobility, namely collaborative effort of teachers and students; online technology and interaction; international and multilingual dimensions and integration of shared understandings that participants might or would not have had opportunity or cause to acquire on their own. As such, DaCaDu represents a valuable alternative to unidirectional or teacher-led approaches for learning about local and global contexts, languages and cultures.

4 THE DA-CA-DU PROJECT



Collaborative Online International Learning – Developing German language skills and IC Competence

The DaCaDu project, Interkulturelles Lernen für Deutschlernende, sought to develop German language skills & intercultural competence, and enhance and develop awareness around multilingualism and plurilingualism through virtual collaboration and engagement with students on three EUt+ university campuses. The project brought together lecturers

18 https://www.simplypsychology.org/vygotsky.html

and students (at various levels on CEFR, and from a variety of disciplines) in collaboration and construction of an online Blog through extensive engagement with and between students from TU Dublin, UPCT Cartagena and Hochschule Darmstadt. This project's goals are envisaged as enhancement, enrichment & curricular activity that converges with the learning outcomes identified in the diverse programmes of study of participants. As a project, it also aligns with the objectives and aspirations around multilingualism and plurilingualism within EUt+.

The Learning outcomes for the DaCaDu project were conceived broadly as development and enhancement of German language writing and speaking skills as well as intercultural exchange. Group discussions were envisaged in German, predominantly, but also as multilingual interactions in the languages shared by participants, English, Spanish & German. Written submission were in German.

Our learner participants included students of German in Cartagena, Dublin and Darmstadt, at levels A1 to B2 on the CEFR, with a hoped-for even distribution across the three campuses. In fact, numbers from UPCT Cartagena and TU Dublin averaged 6, the cohort from h-da Darmstadt was 13. The invitation to participate had been extended to student groups as an embedded co-curricular initiative, in some campuses participants could choose to a greater extent whether to participate in what was for them an extra-curricular initiative. 19 students participated.

Interactions and supports included online group meetings, submission and editing (by teacher) of written posts for blog; for some these were assessed as part of German courses, for others they constituted additional writing practice, WhatsApp and MS Teams cross-campus and multilingual discussion groups (one participant at least from each university).

Project Timeframes

The project ran from April – June 2022, with most student interaction over a 6-week intensive period in April and May. Stimulus materials were edited and re-worked by the lecturers/authors included the Neuland LOGBUCH, a Bundeszentrale für Politische Bildung publication designed for younger people adapting to life in Germany. Lecturers also adapted and created new resources to design themed activities and worksheets for weekly individual and group work and writing or oral submissions.

The project had a number of phases. Before the intensive collaboration period we focused as follows: Pre-delivery, Jan - March 2022[19]:

- Creation of the blog/website in collaboration with students of media and Communications h_da. https://interculturalblog-hda.de/[20]
- Identification and sourcing of resources, permissions, access modes, consent etc.
- Selection of topics/themes. Outline of areas for blog.

19 Most actions continued, in fact, throughout the project as academic calendars, different teaching and exam schedules, students own commitments all meant a degree of continuous follow-up and some degree of flexibility with projected timelines.

20 The blog/website is expected to be accessible to university communities and interested educators by mid/late June 2022

- Compilation of interested participants, group lists, email and telephone numbers
- Communications about the project (blog orientation & access, groups, course schedule, set-up meetings

During the project, most of our efforts were focused as follows:
Intensive collaboration period – April & May 2022:
- Liaison & technical monitoring; support for and from h-da blog team
- Distribution of online worksheets/LOGBUCH; discussion and completion
- Individual writing - reflection on topics such as self, experiences of language, first encounters in Germany/with German, student life, universities, experiences/expectations/ realities of life in Germany, diversity in their cities, tastes, universities etc. & discussion in German classes
- Asynchronous WhatsApp & Teams meetings in small cross-campus multilingual groups
- Creation and editing of individual and group entries for Blog

In the final stage of the project, and after most student participation and collaboration had concluded our efforts focused on the following Post-intensive collaboration – May & June 2022:
- Evaluation of project by participants; students and lecturers.
- Evaluation and consideration of findings – insights, experiences, scalability, recommendations
- Dissemination and presentation (Educational Explorers TU Dublin, TU Summit Darmstadt, Rise[21]

5 CONCLUSIONS, OBSERVATIONS AND PRELIMINARY RECOMMENDATIONS

While formal evaluation is still ongoing and both written and recorded submissions have provided us with some rich data, there are some preliminary conclusions and insights to share. We consciously chose not to work with one of the partner-supported VLE's for the additional training time it would have required. To sustain such collaborative initiatives, however, existing VLE's could certainly be considered. The creation of the blog, moreover, as a separate and distinct product or resource co-created and curated by students – and perhaps because of this - has been cited as a highlight for many participants (achieving a 5-star rating from all respondents in evaluation survey). In a blog entry focusing on participants' perceptions of diversity, for example, students clearly articulated understanding, value and enjoyment in learning in multilingual and plurilingual settings.

Written contributions from students (English Translation):

"The two words that explain diversity in our group: multilingual and multicultural. Because of multilingualism, we all speak many languages and the two languages that bring us clos-

21 21 Polytechnic Summit 2022, Hochschule Darmstadt 28June to 1 July 2022. https://isu.h-da.de/singleview-isu?tx_news_pi1%5Baction%5D=detail&tx_news_pi1%5Bcontroller%5D=New s&tx_news_pi1%5Bnews%5D=9351&-cHash=5f83cd1dfcc746a533e13951d2d4 e5f3

er together are English and German. One day Augustin and Max taught me Spanish. That was fun."

"My personal opinion is that it is important to learn about and integrate into different cultures, because we will encounter people from different cultures at different stages of our lives, perhaps as international students or as clients in our workplace, etc."

Intrinsic motivation in the participants, for example, was high, over 85% indicated a strong individual desire to participate, with no indication that peer influences or grades played a role. Approx 60% disagreed with statements that linked their motivation with grade improvement.

For me, pursuing master's in Germany is also about gaining cultural experiences. The project was an open door to interact with students across Europe and I thoroughly enjoyed sharing my experiences, learning about students across universities in Europe, to draw a virtual picture of Germany for them and of course, to kindle new friendships. The exercises were simple and to the point, which served as good topics to begin with, exchange and definitely improve my German. I thank the project for giving me an opportunity to be a part of it and further collaborate.

Almost 95% confirmed that 'desire to improve IC competence by engaging and collaborating with others' was a motivation, indicating strong understanding of and commitment to IC competence. Participants' evaluative comments show high degrees of satisfaction and plenty of scope for development (see sample below):

'The DaCaDu Project was an excellent experience [ ] The DaCaDu project was very well organised with clear assignments and pre organised groups. I would definitely recommend this project to future students if the possibility arises'.

'I would like to have been able to do a few more posts because writing them and supplying pictures was really fun.

'I was motivated to be a part of this project for two reasons - cultural learnings through students across Europe and improve my German. I am very content with the quality of activities that were given which enabled me to actively learn about each other'.
'This experience has been helpful in different ways. I learnt German by speaking with my partner and I was helped by her anytime I needed. I learnt a lot from her and I loved hearing and sharing experiences. I also like the way this project is being developed but I consider that it should be longer'

The summary of evaluation results, presented below, presents a generally positive picture of the motivation, learning and experiences of participants, highlighting the value of such online collaboration and the potential benefits in bringing students together for discipline-focused international experiences.
Survey participation: n=19 (19 of 20 participants)

1 *LANGUAGE*

- Languages of participants: three to six languages (Q1)
- Current German level (CEFR):(Q2: 3-A1, 4-A2, 10-B1, 2-B2)
- Language used in conversations: a mix of German, English and Spanish (Q3: 12 of 19)

2 *MOTIVATION*

- High intrinsic motivation in the participants
- Main motivation: "the desire to improve intercultural competence by working with others" (15 of 19 strongly agree)
- Importance of lecturer: "lecturer was enthusiastic and encouraged me" (16 of 19 strongly agree)

3 *EXPERIENCE*

- Enjoyment of interaction with students (all agree or strongly agree)
- Problems of arranging conversations or meetings with student group via WhatsApp or other medium

4 *LEARNING*

- Opportunity to develop written and oral German (19 agree/strongly agree)
- Development of intercultural competence (19 agree/strongly agree)
- Enjoyment of sharing experiences of language and culture with other students (18 agree/strongly agree)
- Enjoyment of reading the different blog entries and comparing submission with others (16 agree/strongly agree)

5 RECOMMENDATION: all would recommend to others (19)

6 SATISFACTION: five of five stars (18)

In conclusion, DaCaDu was a very positive, if a busy and intensive experience for lecturers and students. Several areas, such as academic schedules and calendars presented challenges, but certainly an initiative to build upon and develop. Benefits to students, as evidenced in DaCaDu project and as suggested in literature, have included the following invaluable opportunities:

- Interaction, engagement and collaboration with peers to develop, in this case, German language skills and IC competence.
- Shared understanding of each others societies, student lives etc. and perspectives to develop intercultural skills and mutual understanding.
- Wide range of skills developed and practised: observation, listening, oral, written, critical and reflective skills. Awareness of communication styles, non-verbal cues and body language (in online environments); increasing capacity for managing interactions in diverse, complex and novel scenarios.
- Experience & interaction in discipline-focused, multilingual and diverse cross-campus teams.
- Development of digital skills for the 21st Century, enabling participation in teamwork over geographically-dispersed locations.

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USING ENTREPRENEURIALLY MINDED LEARNING TO DEVELOP INTERCULTURAL COMPETENCE AS IT RELATES TO GLOBAL AND CORPORATE CULTURE

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ABSTRACT

Many traditional STEM programs continue to teach using methods and content that negates knowledge and skill development required of today's job market and that of the future. Due to this challenge and the continued rapid growth in the numbers of culturally and linguistically diverse students in schools, intercultural competency needs to be emphasized to respond to the nation's need for a stronger STEM education and workforce. The purpose of this study is to show an approach to develop intercultural competence in the STEM classroom using entrepreneurially minded learning and the cultural context of global and corporate cultures. This study contributes to the literature in that it provides two different examples of how to incorporate intercultural competence into the STEM classroom. One module focused on global culture and the other module focused on corporate culture. The preliminary results showcased in this study suggest that career preparedness and intercultural competence learning outcomes are similar across the two different culture-focused modules. This finding is optimistic, especially considering corporate culture (in comparison to the traditional notion of culture from the global perspective) may be more relevant and understood by both STEM faculty and students, alike.

1 INTRODUCTION

The term STEM (science, technology, engineering, and mathematics) has gained importance over the years due to the pertinence and crucial relevance of the disciplines that are part of this cluster that improve economic and technological development globally. However, many traditional STEM programs continue to teach curriculum using methods and content that negates knowledge and skill development required of today's job market and that of the future (Bunshaft et al., 2015). Even though STEM programs have successfully prepared STEM graduates with the technical and analytical skills necessary for the workplace, intercultural skills are generally lacking in these students. This is problematic because intercultural competence development is crucial in many aspects while preparing students for the job market. First, to create awareness of the interconnectedness of global issues; second, to consider different perspectives; third, to understand the dynamics of multicultural settings and lastly, to work and communicate more efficiently in a globalized world (López-Rocha, 2021). Moreover, due to the rapid growth in the number of culturally and linguistically diverse students in schools, cultural competency needs to be emphasized to respond to the nation's need for a stronger STEM education and workforce (Santiago, 2017).

It is important to acknowledge that many higher education institutions have recognized the need to work towards this problem. Currently, there are several approaches to integrating intercultural competence into the university study experience which include study abroad programs, minors in Global Studies, diversity initiatives (e.g., NSF broadening participation), and the Fulbright scholarship program. These approaches are a great starting point for obtaining intercultural skills, but they have gaps. First, study abroad programs, minors and diversity initiatives offered at universities are optional for students to apply. As such, they require extra resources (e.g., time and money) which limits access to the larger undergraduate student population. Second, increasing student mobility or providing an internationalized university environment that offer students an intercultural experience does not necessarily lead to intercultural learning. Finally, the outcomes of study abroad experiences are variable and difficult to measure, which further increases the complexity of incorporating intercultural competence development into internationalization plans (López-Rocha, 2021; Root & Ngampornchai, 2013).

To overcome these gaps, in this study it is posited that to develop meaningful learning outcomes, intercultural competence needs to be further contextualized within the disciplinary classroom and aligned to specific cultures and professional contexts (Gregersen-Hermans, 2017). One approach to integrating intercultural competence into the STEM classroom is through entrepreneurially minded learning. To shape an entrepreneurial mindset, students need clear objectives and understanding, embedded with multidisciplinary knowledge and competencies, to implement it in business practice and turn challenges into functional solutions (Badzińska & Timonen, 2019). The purpose of this study is to show an approach to develop intercultural competence in the STEM classroom using entrepreneurially minded learning and the cultural context of global and corporate cultures. The guiding research questions are as follows:

- What are the impacts of using entrepreneurially minded learning and intercultural competence learning to influence student perceptions of career preparedness?
- How do learning outcomes vary across global culture and corporate culture curriculum?

2 BACKGROUND / LITERATURE REVIEW

2.1 VALUE RUBRICS - INTERCULTURAL KNOWLEDGE AND COMPETENCE

Intercultural Knowledge and Competence is defined as "a set of cognitive, affective, and behavioral skills and characteristics that support effective and appropriate interaction in a variety of cultural contexts" (Bennett, 2008). The Association of American Colleges and Universities (AAC&U) has established six dimensions related to the Intercultural Knowledge and Competence VALUE Rubric which include (1) cultural self-awareness, (2) knowledge of cultural worldview frameworks, (3) empathy,

(4) verbal and non-verbal communication, (5) curiosity, and (6) openness (Association of American Colleges and Universities (AAC&U), 2009). Recommendations and assessment of intercultural competence in the literature are sparse, yet a few key studies related to the higher education STEM setting have recently emerged. MacCleoud published information on motivating STEM students, in particular, to develop intercultural competence so they can be prepared to partner with employees and supply chain representatives from diverse backgrounds and living in locations throughout the world (MacCleoud, 2018). Anderson distills the AAC&U intercultural competence down to three key behaviors including critical global citizenship, global readiness, and critical digital literacy (Anderson, 2020). Akdere and colleagues conducted a study with one-hundred and one (101) first-year undergraduate STEM students enrolled in an entry-level technology course (Akdere et al., 2021). The study aimed to investigate the efficacy of virtual reality technology in developing intercultural competence, attitudes, and beliefs. The study's findings

support the benefit of immersive intercultural experiences, especially using virtual reality as a substitute when travel is not an option.

Teaching intercultural competence has many benefits to students. Huang et al. (2003) stated one of the main benefits of intercultural competence is the ability to maintain the quality of business relationships with parties from different countries. Barletta Manjarrés (2009) stated that teaching intercultural competence gives two main benefits to students: (1) the ability of interpreting, comparing, and contrasting texts and events and (2) the ability to analyze data of one's own country and other countries to explore the relationship between them. Yet, teaching intercultural competence has its challenges. In general, content can be difficult to access, and educator competency related to discourse information about other cultures and countries is limited (Barletta Manjarrés, 2009).

2.2 TYPES OF CULTURE

There are many types of culture. In the globalization era, intercultural competence is highly desirable (Snow, 2015). The term 'intercultural competence' is a general term that covers a wide spectrum of skills, attitudes, and knowledge (Snow, 2015). Given that English is the most widely used language in the world, English has become the tool to interact with people and cultures around the world or as one of the most important set of skills of intercultural competency (Snow, 2015).

For the purpose of this paper, we will discuss global culture and corporate culture. First, Featherstone (1990) defined global culture as a globalization of culture where cultural integration and disintegration processes are happening on a trans-national or trans-societal level. Second, corporate culture, as defined by Belkaci and Mekbel (2021) is "the characteristic and the tangible personality originated inside every organization". In their paper, Belkaci and Mekbel (2021) also explain that company culture can become the company image. In the context of international business, where global culture and corporate culture are intertwined, Leung et al. (2005) explained that multinational companies are often faced with the challenge of whether the company program should be implemented in the same manner or modified according to local culture. Furthermore, they explained that the top-down process, from the global culture level to the individual level, may change the culture of the individual. Finally, the study emphasized this point by explaining the current cognitive psychology study that explained the human mind is fluid and adaptive to the environment.

2.3 ENTREPRENEURIALLY MINDED LEARNING

The entrepreneurial mindset is defined as "the inclination to discover, evaluate, and exploit opportunities" (Bosman & Fernhaber, 2018, p. 13; Bosman & Fernhaber, 2021). Here, it is important to note that developing one's entrepreneurial mindset is not just for startups, instead, it can benefit people from all disciplinary backgrounds in thinking more strategically and focusing more on value creation when working within an organization or even in one's personal life. With the efforts of the Kern Entrepreneurship Education Network (KEEN), entrepreneurially minded learning has been integrated into engineering courses throughout higher education institutions in the United States (Bosman & Fernhaber, 2019; Bosman et al., 2020; Santiago & Guo, 2018). Implementing entrepreneurially minded learning in the higher education classroom requires four key intentions (Bosman & Fernhaber, 2018). First, the lesson topic must intersect with the entrepreneurial component. Thus, instead of the entrepreneurial component being a stand-alone lecture offered by a visiting lecturer from the business school, it should be presented and taught in a manner that intersects with the course topic. For example, if the course topic is food science, the learning approach should look at opportunity recognition (i.e., commercialization, value, and design) within the context of food science. Second, the lesson topic should incorporate opportunities for developing professional skills including communication and collaboration, as these are regularly listed as the most important interpersonal skills demanded of college and university graduates by industry. Third, the lesson topic should provide opportunities for practice, feedback, and reflection. This assists in developing the 'mindset' part of the entrepreneurial mindset. Fourth, the lesson topic should be grounded in backward course design whereby the learning goals, learning objectives, learning activities, and learning assessment are all in alignment (Wiggins & McTighe, 2005).

3 METHODS

3.1 PARTICIPANTS

Participants for this study included eight senior-level students (four female and four male) enrolled in a course titled, "Leadership Strategies for Quality and Productivity." The course catalog description is as follows: "This course is a study of how organizational leaders create an environment conducive to high levels of employee self motivation, quality, and productivity. Emphasis is placed on process and systems thinking. Actual case situations, experiences, and applications from current events are used to illustrate the application of course content. The intent is to provide students with profound knowledge, understanding and leadership practices which are essential for establishing and continually improving organizational effectiveness through the prevention and solution of workplace problems."

3.2 STUDY DESIGN

At the start of the semester, participants completed a pre-survey. During the semester, participants completed two (2) five-week modules which culminated with a project. Upon completion of the project, participants submitted a post-survey debrief. The first section provides an overview of the assignments leading up to the project and the second section provides an overview of the culminating project requirements.

3.2.1 OVERVIEW OF ASSIGNMENTS (WEEKS 1-4)

For each module, each week required participants to complete a Microsoft Power BI tutorial to gain practice with data analysis, visualization, and interpretation. Additionally, during each week, scaffolding was promoted by first completing in-class assignments in groups (applied learning based on the lecture content using Google Docs), and then participating in an online discussion as an individual (completing a task similar to the in-class assignment). This was intended to allow for sufficient feedback in preparing students to complete the culminating project, where they had the opportunity to demonstrate learning for the third time. Module #1 had a focus on global culture and is summarized in Table 1. Module #2 had a focus on corporate culture and is summarized in Table 2.

Week	Lecture Topics	Assignments
1	Intro to Microsoft Power BI	Microsoft Power BI Tutorial
2	Customer Focused Quality, Hofstede's Value Dimensions	Microsoft Power BI Tutorial, Collaborating via Google Docs, Information Literacy and Identifying Credible Sources
3	Workforce Focused Quality, Hofstede's Value Dimensions	Microsoft Power BI Tutorial, Collaborating via Google Docs, Canva.com, and Storyboard Creation
4	Process Focused Quality, Hofstede's Value Dimensions	Microsoft Power BI Tutorial, Collaborating via Google Docs, Poka-yokes, Executive Memos
5	Project Week (see Table 3 for project details)	

Table 1. Module #1 - Overview of Assignments (Global Culture Focus)

Week	Lecture Topics	Authentic Learning (Workforce Preparation)
1	Data Analysis and Interpretation Using Microsoft Power BI	Microsoft Power BI Tutorial, Collaborating via Google Docs
2	Six Sigma Tools and DMAIC	Microsoft Power BI Tutorial, Collaborating via Google Docs, A3 Report Creation
3	Using Data to Justify Problems and Propose Solutions	Microsoft Power BI Tutorial, Collaborating via Google Docs, Executive Memo Creation
4	Understanding Decision Maker Archetypes	Microsoft Power BI Tutorial, Collaborating via Google Docs, Targeted Communication via Executive Memo and Infographic
5	Project Week (see Table 4 for project details)	

Table 2. Module #2 - Overview of Assignments (Corporate Culture Focus)

3.2.2 OVERVIEW OF PROJECT REQUIREMENTS (WEEK 5)

The project for Module #1 had a focus on global culture and is summarized in Table 3. The project for Module #2 had a focus on corporate culture and is summarized in Table 4.

You recently graduated from university. Not surprisingly, due to COVID-19, the job market is very competitive. You've identified the perfect job posting working with International Consulting Company XYZ. To help give you a leg up on your competition, you decide to do some pro bono work in an effort to showcase your skillsets and provide value to your potential future employer.

Part A (Customer Focused Quality): Similar to the in-class assignment and online discussion, provide examples of quality dimensions (e.g., performance, features, conformance, reliability, durability, serviceability, and aesthetics) as it relates to a (A) manufactured product and (B) service product. Taking into consideration what you've learned about **Hofstede's value dimensions**, be sure to **ONLY reference products in countries outside the United States**. Be sure to explain how **Hofstede's values** play a role concerning the example quality dimensions identified. Moreover, in the executive memo, you will need to **justify** how this information is relevant to **International Consulting Company XYZ**.

Part B (Workforce and Process Focused Quality): Similar to the in-class assignment and online discussion, provide examples of behavior goals, motivational interventions, and poka-yokes (e.g., mistake proofing) using the organizational performance metrics of safety, quality, productivity, and cost. Taking into consideration what you've learned about **Hofstede's value dimensions**, be sure to **ONLY** ref**erence organizations in countries outside the United States**. Be sure to explain how **Hofstede's values** play a role concerning the example quality dimensions identified. Moreover, in the executive memo, you will need to **justify** how this information is relevant to **International Consulting Company XYZ**.

Part C (Storyboards): Using Canva.com, you will create a storyboard for both Part A and Part B, aimed to visually highlight various approaches to each of the quality focus areas (customer, workforce, and process) applied in a manner **unique to a specific country**. The storyboard should include pictures and a brief explanation of how the picture responds to the dimension.

Part D (Executive Memo): Use the university approved letterhead to summarize the storyboard findings and explain **why you would be a good fit to work at the International Consulting Company XYZ.** Be sure to keep the formatting provided within the downloaded letterhead and fill the entire page with the following items: (1) greeting, (2) hook/introduction, (3) key message, (4) conclusion, and (5) salutation.

Table 3. Module #1 - Overview of Project Requirements (Global Culture Focus)

You recently graduated from university. Not surprisingly, due to COVID-19, the job market is very competitive. You've identified the perfect job posting working with the government on a new administration initiative related to technology leadership and innovation. To help give you a leg up on your competition, you decide to do some pro bono homework in an effort to showcase your skillsets and provide value to your potential future employer. **Part 1 (Problem Identification and Microsoft Power BI)** As you previously learned, problems can typically be categorized according to the following: **safety, quality, productivity/delivery, and cost considerations**. In addition, solutions can typically be categorized according to the following: **behavior change, policy change, process redesign, and new product/service development**. Identify a dataset of your choosing and use Microsoft Power BI to create at least visualizations justifying the problem. Then, briefly summarize a proposed solution. **Part 2 (Communicate Findings via Formal A3 Report)** Based on the information in Part 1, create an **A3 Report** to summarize and communicate the findings. **Part 3 (Communicate Findings via Informal Infographics)** Based on the information in Part 1, use Canva.com to create two different infographics, each **targeting a different type of Decision Maker: The Charismatic, The Deep Thinker, The Skeptic, The Follower, and The Controller**. **Part 4 (Communicate Findings via Executive Memo)** Use university letterhead to summarize the Power BI Data Analysis, A3 Report, and infographics in an executive memo (note: the A3 report and infographic should be attached as supplemental documents, but still referenced within the memo). Select one type of **Decision Maker to address the memo (e.g., Dear Charismatic Supervisor, Dear Skeptic Supervisor, etc.).**

Table 4. Module #2 - Overview of Project Requirements (Corporate Culture Focus)

3.3 DATA COLLECTION

3.3.1 PRE-SURVEY

During the first class session, participants completed the pre-survey shown in Table 5. The purpose of the pre-survey was to gain an understanding of student experience with technology tools including Microsoft Power BI (required for tutorials), Canva.com (required to make storyboards), and Google Docs (required for collaborative in-class assignments).

Prior Experience: What is your level of experience with each of the following? [Never Used = 1, Novice = 2, Intermediate = 3, Expert = 4]
Microsoft Power BI Desktop
Canva.com
Google Docs

Table 5. Pre-Survey

3.3.2 POST-SURVEY FOR MODULE 1 AND MODULE 2

Upon completion of each module (after the project was submitted), participants completed the post-survey shown in Table 6. The purpose of the post-survey was to assess student perceptions of career preparation and intercultural competence gains as a result of completing the module.

Career Preparation: This module was designed to provide authentic experiences similar to what you can expect in the workforce. Please respond to the following statements with respect to the five-week module (assignments + project). [Strongly Disagree = 1, Disagree = 2, Somewhat Disagree = 3, Somewhat Agree = 4, Agree = 5, Strongly Agree = 6]
In this module, information was taught in a way that is relevant to my career goals.
In this module, the content was similar to the types of problems I'd like to solve in the future.
In this module, the skills developed will help me to meet my career goals.
In this module, I am confident in my ability to document skills learned on a resume.
In this module, the work I did was realistic compared to what I think professionals are doing in the field.
In this module, I felt appropriately challenged by the assignments.
In this module, I was able to practice written communication skills.
In this module, I was able to practice visual communication skills.
In this module, the problems and assignments completed were a good use of my time.
In this module, the assignments were reflective of the problems professionals are solving.
Intercultural Competence: This module required you to flex your intercultural competence muscle. Please respond to the following statements with respect to the five-week module (assignments + project). [Shows minimal awareness = 1, Identifies rules and biases = 2, Recognizes new perspectives = 3, Articulates insights = 4]
To what extent do you feel you were able to demonstrate Cultural Self-Awareness?
To what extent do you feel you were able to demonstrate Knowledge of Cultural Worldview Frameworks?
To what extent do you feel you were able to demonstrate Intercultural Empathy?
Use 2-3 sentences to explain your selection for Cultural Self-Awareness.
Use 2-3 sentences to explain your selection for Knowledge of Cultural Worldview Frameworks.
Use 2-3 sentences to explain your selection for Intercultural Empathy.

Table 6. *Post-Survey for Module 1 (Global Culture) and Module 2 (Corporate Culture)*

4 RESULTS AND DISCUSSION

4.1 PRE-SURVEY (PRIOR EXPERIENCE)

The pre-survey results, inquiring on students' prior experience, are shown in Table 7. The results show students have had a good amount of prior experience working with Google Docs. However, prior experience with using Microsoft Power BI Desktop and Canva.com, both of which are freely available, was limited. This confirmed the instructor's intuition. As a consequence, the curriculum was designed in a way to offer a greater focus on Microsoft Power BI Desktop and Canva.com.

Prior Experience: What is your level of experience with each of the following? [Never Used = 1, Novice = 2, Intermediate = 3, Expert =4]	Avg	Std Dev
Microsoft Power BI Desktop	1.13	0.35
Canva.com	1.88	0.99
Google Docs	3.63	0.52

Table 7. Results of Pre-Survey

4.2 POST-SURVEY

4.2.1 POST-SURVEY – CAREER PREPARATION (MODULE 1 VS. MODULE 2)

The post-survey results, for Module 1 (global culture focus) and Module 2 (corporate culture focus), are summarized in Table 8. For the vast majority of items, students scored Module 2 higher than Module 1. This implies one of two things. First, corporate culture may be easier for students to understand and relate to in comparison to global culture, especially if students have not traveled much or participated in a study abroad opportunity. This likely could be the case given that travel has been limited due to the COVID-19 pandemic. Second, corporate culture may be easier for the instructor to grasp and teach students, in comparison to global culture. Yet, the instructor has a vast amount of international travel experience as well as industry experience (working as a manufacturing engineer).

Career Preparation: This module was designed to provide authentic experiences similar to what you can expect in the workforce. Please respond to the following statements with respect to the five-week module (assignments + project). [Strongly Disagree = 1, Disagree = 2, Somewhat Disagree = 3, Somewhat Agree = 4, Agree = 5, Strongly Agree = 6]	Module 1: Global Culture (Averag e)	Module 2: Corporat e Culture (Averag e)
1. In this module, information was taught in a way that is relevant to my career goals.	4.5	5.33
2. In this module, the content was similar to the types of problems I'd like to solve in the future.	4.25	4.67
3. In this module, the skills developed will help me to meet my career goals.	4.75	5.00
4. In this module, I am confident in my ability to document skills learned on a resume.	4	4.67
5. In this module, the work I did was realistic compared to what I think professionals are doing in the field.	4	4.83
6. In this module, I felt appropriately challenged by the assignments.	4.75	4.83
7. In this module, I was able to practice written communication skills.	5.25	5.33
8. In this module, I was able to practice visual communi-cation skills.	5.25	5.17
9. In this module, the problems and assignments complet-ed were a good use of my time.	4.5	4.83
10. In this module, the assignments were reflective of the problems professionals are solving.	4.75	4.83

Table 8. Results for Post-Survey (Career Preparation)

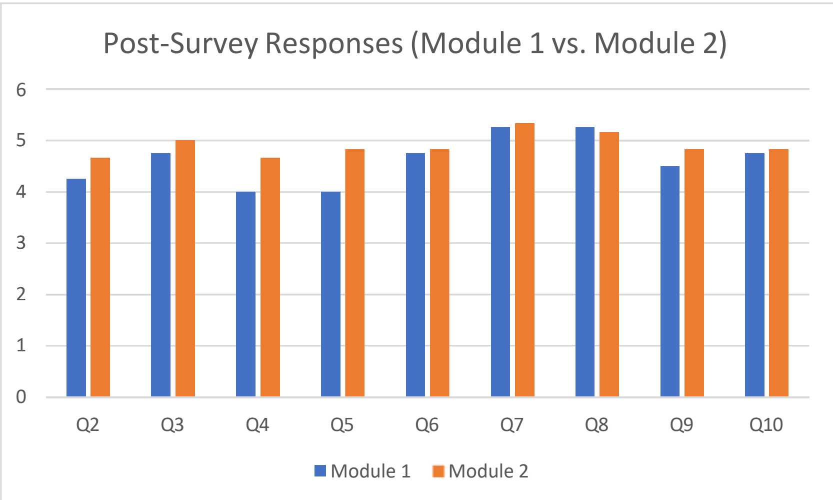

Figure 1. Visual Results for Post-Survey (Career Preparation)

4.2.2 POST-SURVEY – INTERCULTURAL COMPETENCE (MODULE 1 VS. MODULE 2)

Table 9 provides the results for the post-survey Intercultural Competence component of Cultural Self-Awareness. The t-test results show no statistically significant difference between the two modules. Yet, Module 2 (corporate culture) had a higher average than Module 1 (global culture).

t-Test: Two-Sample Assuming Unequal Variances		
Intercultural Competence: To what extent do you feel you were able to demonstrate **Cultural Self-Awareness**? [Shows minimal awareness = 1, Identifies rules and biases = 2, Recognizes new perspectives = 3, Articulates insights = 4]	Module 1 (Global Culture)	Module 2 (Corporate Culture)
Mean	2.33	2.8
Variance	1.33	0.7
Observations	3	5
Hypothesized Mean Difference	0	
df	3	
t Stat	-0.61	
P(T<=t) two-tail	0.58	
t Critical two-tail	3.18	

Table 9. Results for Post-Survey (Intercultural Competence - Q1: Cultural Self-Awareness)

Example student justification quotes are as follows. <u>Module 1 (Global Culture)</u>

- "In this project, I was able to recognize new perspectives about cultural rules here in the US by searching workplace norms and what these organizations do for the people."
- "I realized that even within my own culture, there are subcultures with differing norms, expectations, roles, and more that impact how organizations operate."
- "I feel I was able to demonstrate my cultural self-awareness through my choices when it came to international products and companies that I chose for the project."

<u>Module 2 (Corporate Culture)</u>

- "I realize that my own rules/biases may not be the only "right" way, and it's important to be mindful of others as well."
- "I don't always think about how my culture impacts my decision-making. I know that my values and beliefs affect that, but I am not always aware in the moment."
- "Through this project, I was able to understand what other cultures and people from different backgrounds experience in our country. Understanding the greater context outside of my own experience with education was a large part of what I needed to do to analyze the data in this project."

Table 10 provides the results for the post-survey Intercultural Competence component of Knowledge of Cultural Worldview. The t-test results show no statistically significant difference between the two modules. Yet, Module 1 (global culture) had a higher average than Module 2 (corporate culture).

t-Test: Two-Sample Assuming Unequal Variances		
Intercultural Competence: To what extent do you feel you were able to demonstrate Knowledge of **Cultural Worldview Frameworks**? [Shows minimal awareness = 1, Identifies rules and biases = 2, Recognizes new perspectives = 3, Articulates insights = 4]	Module 1 (Global Culture)	Module 2 (Corporate Culture)
Mean	2.33	2
Variance	0.33	0.5
Observations	3	5
Hypothesized Mean Difference	0	
df	5	
t Stat	0.73	
P(T<=t) two-tail	0.50	
t Critical two-tail	2.57	

Table 10. Results for Post-Survey (Intercultural Competence - Q2: Cultural Worldview Frameworks)

Example student justification quotes are as follows. <u>Module 1 (Global Culture)</u>

- "This module showed me that many elements of an organization are intertwined. This also applies internationally; many organizations are interdependent on others, and it is important to recognize this network."
- "I think that I could have done more research into the different cultures and figured out how these countries operate compared to ours."
- "Knowledge of cultural worldview frameworks is not something one can figure out overnight it takes time to understand how organizations do things outside of the United States. I feel as if I have learned some on this level."

<u>Module 2 (Corporate Culture)</u>

- "As much as I engaged in research to better understand this, I still feel as though there was a lot more I could have understood with this issue."
- "Religion, geography, gender, and many more play important roles in cultures and all vary in different ways. I feel I have a basic knowledge of this understanding but do not know all the history."
- "I have a good understanding of different elements of culture, and that they are interconnected in a complex manner."

Table 11 provides the results for the post-survey Intercultural Competence component of Intercultural Empathy. The t-test results show no statistically significant difference between the two modules. In this case, Module 1 (global culture) and Module 2 (corporate culture) had similar averages.

t-Test: Two-Sample Assuming Unequal Variances		
Intercultural Competence: To what extent do you feel you were able to demonstrate **Intercultural Empathy**? [Shows minimal awareness = 1, Identifies rules and biases = 2, Recognizes new perspectives = 3, Articulates insights = 4]	Module 1 (Global Culture)	Module 2 (Corporate Culture)
Mean	2.67	2.6
Variance	0.33	0.8
Observations	3	5
Hypothesized Mean Difference	0	
Df	6	
t Stat	0.13	
P(T<=t) two-tail	0.90	
t Critical two-tail	2.45	

Table 11. Results for Post-Survey (Intercultural Competence - Q3: Intercultural Empathy)

Example student justification quotes are as follows.

Module 1 (Global Culture)

- "I have tried to study abroad the past two years but because of COVID it has been canceled and I feel as this would've given me more insight."
- "I don't think that anything is weird or off about these other cultures, but I do think they are interesting and make me want to meet people from said culture."
- "By putting myself in their shoes, I practiced this skill of intercultural empathy and recognized the different dimensions pertaining to organizational operations."

Module 2 (Corporate Culture)

- "I am able to recognize the viewpoints of others from different cultures and empathize with them."
- "I do believe that I have the capability of perceiving the world from a different perspective, I just, unfortunately, have a hard time with that which causes me to stick to my own understanding of things."
- "I identified components of other cultural perspectives within this project mainly through the literature review that was required."

5 CONCLUSIONS AND DISCUSSION

5.1 PRACTICAL IMPLICATIONS

What are the impacts of using entrepreneurially minded learning and intercultural competence learning to influence student perceptions of career preparedness?

In response to the first research question (provided above), Table 7 showed that students had limited prior experience with Microsoft Power BI Desktop and Canva.com. In addition, Table 8 showed high post-survey scores for both Module 1 (global culture focus) and Module 2 (corporate culture focus). The highest scored survey items across both Modules are as follows:

- 1. In this module, information was taught in a way that is relevant to my career goals.
- 3. In this module, the skills developed will help me to meet my career goals.
- 7. In this module, I was able to practice written communication skills.
- 8. In this module, I was able to practice visual communication skills.

This suggests that teaching using the pedagogical approaches of entrepreneurially minded learning and intercultural competence learning does indeed positively impact career preparedness. In other words, the modules were taught in a way that provided an authentic experience similar to what the students might expect in the workforce.

How do learning outcomes vary across global culture and corporate culture curriculum?

In response to the second research question (provided above), Table 9, Table 10, and Table 11 provide the post-survey t-test results for the Intercultural Competence components of Cultural Self-Awareness, Knowledge of Cultural Worldview, and Intercultural Empathy, respectively. In all three cases, the t-test results show no statistically significant difference between the two modules. As such, it is safe to say that both modules provide comparable learning outcomes. This suggests that both cultural focus areas (global culture and corporate culture) are appropriate to enhance student learning as it relates to intercultural competence.

The results of this exploratory study are optimistic. Future teaching and research efforts will involve using bigger sample sizes and integrating the modules into different courses in an attempt to validate repeatability, reliability, and generalizability.

5.2 CONCLUDING REMARKS

Many traditional STEM programs continue to teach using methods and content that negates knowledge and skill development required of today's job market and that of the future (Bunshaft et al., 2015). Due to this challenge and the continued rapid growth in the numbers of culturally and linguistically diverse students in schools, intercultural competency needs to be emphasized to respond to the nation's need for a stronger STEM education and workforce (Santiago, 2017).

This study contributes to the literature in that it provides two different examples of how to incorporate intercultural competence into the STEM classroom. One module focused on global culture and the other module focused on corporate culture. The preliminary results showcased in this study suggest that career preparedness and intercultural competence learning outcomes are similar across the two different culture-focused modules. This finding is optimistic, especially considering corporate culture (in comparison to the traditional notion of culture from the global perspective) may be more relevant and understood by both STEM faculty and students, alike. By integrating intercultural competence into the STEM classroom, instructors provide ALL students access and equity to cultural learning experiences, especially when study abroad opportunities may be limited by the COVID-19 pandemic and for students who simply don't have the time and resources to embark on an out-of-country journey.

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