Danish Technological Institute
Centre for Policy and Business Development

Fostering innovation through applied research

Global best practice study

CHALLENGER

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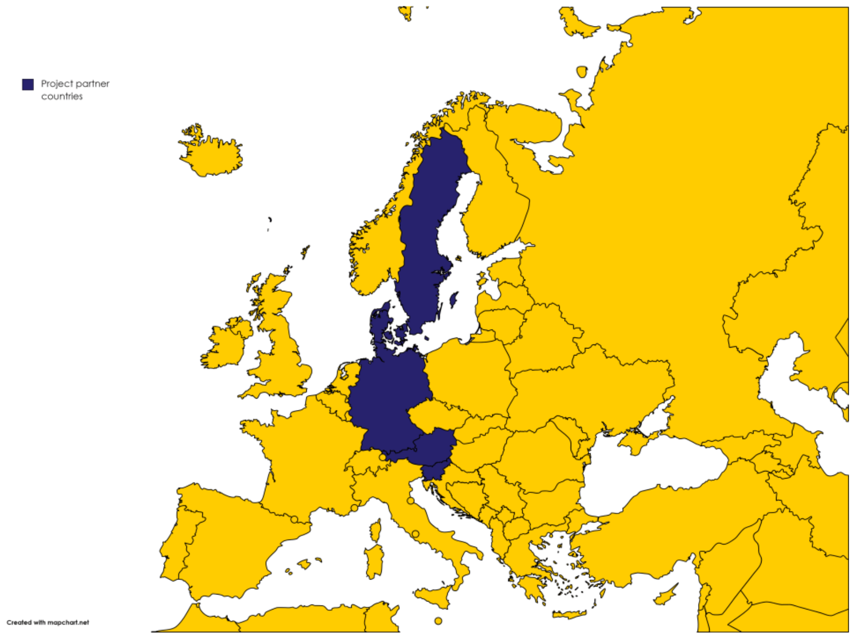

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Prepared by:

DANISH TECHNOLOGICAL INSTITUTE

Centre for Policy and Business Development

Authors:

Andreas Bjerre Lunkeit, Emil Højbjerre Thomsen, Karsten Frøhlich Hougaard, Kristian Kriegbaum Jensen and Nikolaj Birkkjær Andersen

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List of abbreviations

- **DF@SIT** *Design Factory at the Singapore Institute of Technology*
- **EQF** *European Qualification Framework*
- **KEA** *Copenhagen School of Design and Technology ('Københavns Erhvervsakademi')*
- **PBL** *Problem-based learning*
- **SIT** *Singapore Institute of Technology*
- **VET** *Vocational education and training*

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I. Introduction

Vocational education and training (VET) is meant to play a key role in the green and digital transitions, which aim to address complex challenges facing Europe (and other parts of the world), such as climate change, population ageing and skill gaps in the labour market (CEDEFOP, 2022). To successfully address these challenges, innovative solutions and technological advancements are needed.

At the same time, the rise of new technologies is changing the nature of many jobs and the skills that they require. The increasing digitalisation and automation of work, for instance, leads to growing demands for a workforce that not only has necessary technical skills, but also is capable of problem-solving and adapting technologies in a rapidly changing world (European Commission, 2020).

On this background, there is a significant need for enhancing the quality of VET to ensure that it can help address current and future skill demands and contribute to the development of innovative solutions to the challenges faced by society.

This report presents the findings and lessons learnt from a best practice study conducted for the Erasmus+ project Challenger. The project's overall goal is to improve the quality and innovation capacity of VET through the integration of applied research. More specifically, Challenger aims to develop a framework for fostering innovative mindsets and entrepreneurship skills among VET students by having them work with and find solutions to real-world problems as part of their education.

The following sections of this chapter introduce the content and focus of the best practice study, while also describing the benefits of applied research as something that can increase the innovation capacity of VET and be applied as a teaching and learning strategy. Chapter II outlines the methodological approach to this study and is followed by a presentation of the five case studies. The concluding chapter III presents key findings and lessons learnt from the case study. It can be read separately and independently from the case studies, providing interested readers with a short cut to main results.

I.I About the best practice study

The global best practice study is a first steppingstone on the way to reaching the overall aim of the Challenger project. Findings from conducted case studies are meant to serve as inspiration for the development of a new framework guiding the integration of applied research into VET. All cases presented in this report provide examples of how applied research can be embedded into education to stimulate both innovation and learning. The list below offers a brief introduction to the five case studies at the heart of this report.

- **Copenhagen School of Design and Technology (KEA), Denmark:** KEA is a so-called business academy (‘erhvervsakademi’), offering practical and industry-focused degree programmes and courses in design, technology, business, and digital communication at EQF level 4 & 5.
- **Design Factory at the Singapore Institute of Technology (SIT), Singapore:** SIT is a publicly funded university of applied sciences offering over 40 different degree programmes at bachelor’s, master’s and doctorate level. The Design Factory is one of several innovation centres and applied research centres that have been established at the university to foster closer collaboration with industry.
- **Holmesglen Centre for Applied Research and Innovation, Australia:** The Holmesglen Institute is a public VET provider in Melbourne. The institution offers a range of courses and programmes in areas such

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as business and finance, building and construction, as well as community and health sciences. Holmesglen's Centre for Applied Research and Innovation was established in 2016 and plays an essential role in the Holmesglen's applied research activities.

- **Saskatchewan Polytechnic, Canada:** Saskatchewan Polytechnic is a public institution that provides technical education and skills training. It offers over 150 educational programmes (e.g., within aviation, engineering, health sciences, and trades). Saskatchewan Polytechnic's applied research programmes provide practical solutions to real-world problems, covering a wide range of fields including agriculture, artificial intelligence, biotechnology, and bio-mechanics. They are coordinated by the institution's Office of Applied Research.
- **Waag Futurelab (Waag), Netherlands:** Waag is a pioneering Dutch NGO based in Amsterdam that has been at the forefront of digital innovation and civic engagement for three decades. The organisation is neither an academic nor an educational institution offering programmes, but rather a collaborative and innovative entity. As part of its activities, Waag provides educational institutions and other stakeholders with advice on how to establish their own lab facilities and engage in 'critical making'.

Four of the five cases focus on the integration of applied research by different educational institutions, ranging from providers of initial and/or higher VET (Holmesglen, KEA, Saskatchewan) to a university of applied sciences (Singapore Institute of Technology). The fifth case study examines applied research activities by the Waag Futurelab, a foundation focusing on the development of technological and social design skills as well as the promotion of social innovation. Chapter II of this report contains a description of how case studies were conducted and thus presents the methodology behind this report.

I.II Promoting innovation in VET through applied research

Applied research aims to find solutions to an immediate problem faced by either individuals, businesses/organisations or society as a whole. In contrast to fundamental research, which is mainly concerned with generalisations and the formulation of theories, applied research seeks to create actionable knowledge that can be manifested in the form of new designs, products or services (Kothari, 2008). Applied research projects are often conducted on behalf of clients or sponsors in need of a solution to a specific, real-world problem. While they can take on different forms, such as design experiments and ethnographic user studies, all applied research projects contribute to innovation, since they are driven by the goal of developing a practical solution to a given problem (Beddie & Simon, 2017a).

At the same time, applied research can be integrated into VET as a teaching and learning strategy providing students with rich learning opportunities through problem-based and 'hands-on' project work. Due to their close ties with industry, VET providers are in an ideal position to stimulate collaborations on applied research projects between students, teachers and industry partners (while such projects also may involve other stakeholders from government or the private sector).

In general, there is a wide range of benefits for all stakeholders involved in VET applied research. VET providers actively contribute to innovation and are able to form more sophisticated partnerships with businesses, research organisations and others in the local community. They can potentially develop new income streams while also being able to produce more employable graduates. The teachers and trainers involved in applied research projects are likely to develop their professional knowledge and capabilities and are thus able to improve their teaching. Next to being provided with real-world experience and industry contacts, students are likely to adopt additional skills in regard to creative thinking, problem-solving and project management. Furthermore,

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businesses can benefit from research outcomes and developed solutions as well as the developed partnerships with VET institutions, which may provide them with inexpensive student engagement. Additionally, direct contact with students is likely to increase chances for businesses to recruit from a greater diversity of talents. Last but not least, the integration of applied research into VET is expected to have system-wide benefits. It is, for instance, being linked to a wider dissemination of innovative ideas and an increase of individuals with an innovation mindset among the workforce. These are important factors when it comes to generating economic activity as well as solving industry and societal problems (Beddie & Simon, 2017b; Packer, 2017).

The project Challenger is not only interested in enhancing the innovation capacity of VET to boost economic growth, but also to help address issues faced by regional and local communities hindering them to thrive. These can range from population loss in rural areas to local impacts of climate change. The inherent focus on collaborative efforts to solve specific problems makes VET applied research well-suited in this context. In addition, involved students are likely to have significant (though somewhat different) learning opportunities regardless of whether their research focuses on improving products for a private business or on helping a local government agency improve its services.

On this background, there is a great opportunity for the VET sector to contribute to innovation for the benefit of the economy and society through an applied research agenda. While some countries may be further ahead than others in terms of implementing this agenda, the project Challenger seeks to further develop the integration of applied research into VET. The five case studies presented in this report (following chapter II) offer inspiration on how this may be achieved as they mainly contain best practice examples focusing on how VET applied research can be organised and conducted.

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II. Methodology

This section outlines the data and methodologies that this best practice study is based on. First, we detail our selected cases, the selection process, and case-specific data. Second, we present the analytical framework used for data collection and analysis. This is guided by five dimensions: 1) Management and organisation, 2) Resources, 3) Approach to innovation and applied research, 4) Impact, 5) Systemic obstacles. Finally, we explain how we combined results from each case study to form a comprehensive understanding of best practices in relation to how applied research can be integrated into VET as a teaching and learning strategy.

II.I Case selection and data

Five cases were chosen from an initial pool of forty potential cases – which had been created with input from all partners in the Challenger project. The selection process was guided by specific criteria and selected cases demonstrate a notable level of success in integrating applied research activities and involving a broader community. Furthermore, these cases showcase the integration of applied research activities as a recurring and integral part of the organisations' operations, rather than as isolated projects. Additionally, the chosen case studies represent diverse geographical locations (being spread across four continents) and institutional contexts. The chosen approach allows us to capture a range of experiences and practices related to applied research and innovation.

Data about applied research activities in each case organisation was gathered via in-depth stakeholder interviews and documents. Between three to five interviews – with some being group interviews – were conducted for each case. Interview persons typically included managers, team leaders, researchers, teachers, facilitators, external partners, and learners. The interviews allowed for a detailed mapping of experiences and practices with regard to the case organisations' applied research and innovation activities.

A supplementary data source were organisational documents. These encompassed strategic plans, project reports, annual reports, and any other written materials that were relevant for applied research activities at case organisations.

II.II Analytical framework

Each case study was conducted with consideration to the unique context, structure, and practices of the organisation in focus. This allowed us to identify salient points and critical success factors specific to each case. Once gathered, the data was meticulously analysed along five crucial dimensions that shape the successful integration of applied research and innovation within the case organisations. These dimensions are:

1. **Management and organisation:** This dimension explores the influence of organisational structure and leadership on applied research and innovation, highlighting the decision-making processes, task distribution, and the role of leadership. Questions under this dimension include: How is the organisation structured to support applied research? What is the role of leadership in facilitating applied research and innovation? How are responsibilities and tasks distributed within the organisation? How are decisions made regarding research directions and priorities?
2. **Resources:** This dimension focuses on the resources necessary for applied research activities, including the availability, allocation, and management of financial, human, and infrastructural resources. Questions under this dimension include: What are the funding sources for applied research? How is funding allocated and managed? What human resources are available (both in terms of quantity and quality)? What kind of infrastructural resources are necessary and how are they utilised for applied research and innovation?

3. **Approach to applied research and innovation:** This dimension investigates organisational strategies and methodologies for applied research and innovation, with a focus on idea generation, pedagogy, and the promotion of creativity. Questions under this dimension could include: What is the organisation's approach to applied research and innovation? How are research ideas generated and selected? How does the organisation ensure the quality and relevance of its research? How does the organisation encourage creativity and out-of-the-box thinking?
4. **Impact:** This dimension evaluates the tangible and intangible effects of applied research activities, assessing the outcomes and how they are tracked, along with the wider influence on the local community. Questions under this dimension might include: What are the measurable outcomes of the organisation's applied research and innovation? How are these outcomes tracked and evaluated? How does the organisation's work influence its community? What are the perceived benefits of the organisation's research and innovation activities?
5. **Systemic obstacles:** This dimension explores the systemic challenges or barriers that may hinder the successful integration of applied research and innovation. Questions under this dimension include: What are the main challenges the organisation faces in conducting applied research and innovation? Are there any bureaucratic or regulatory obstacles? How does the organisation handle setbacks or failures? What measures are taken to overcome these obstacles?

The five dimensions outlined above provide a comprehensive framework for understanding the different factors at play in the case organisations and their approach to organising and conducting applied research activities. By using the framework, this best practice study aims to provide valuable insights into key elements for a successful integration of applied research and innovation into VET.

II.III Synthesis of findings

Following the detailed examination of each case, we conducted a cross-case analysis, where we compared findings from each case. This comparative analysis allowed for the identification of common patterns and themes across multiple cases.

Main findings and lessons learnt are presented in chapter III – following the five case studies. They are based on identified common themes as well as unique insights that stood out in individual cases. Furthermore, we consider the wider applicability of these lessons, bearing in mind the unique context of each case organisation. In this manner, we are able to present both common best practices and unique strategies that have proven successful in specific contexts.

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Global best practices

Case studies

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A. Copenhagen School of Design and Technology (KEA)

1. Introduction

The Copenhagen School of Design and Technology (Københavns Erhvervsakademi, KEA) is an educational institution located in Copenhagen, Denmark. As a so-called business academy, it offers practical and industry-focused degree programmes and courses in design, technology, business, and digital communication at EQF level 4 and 5. The school's curriculum is developed in collaboration with industry experts ensuring that students receive relevant education. KEA provides sophisticated facilities, including design studios, laboratories, and workshops allowing students to engage in first-hand experimentation. With a diverse community of students from around the world, the school offers a multicultural learning environment. Students are encouraged to participate in real-world projects and internships to gain practical experience and build professional networks.

Figure 1: KEA campus housing degree programmes and courses in technology. It is one of five KEA campuses in the Copenhagen metropolitan area. (Image: KEA)

As a part of the Danish business academy system, KEA is required to conduct applied research projects to provide research-based education. Further, teachers at KEA are required to complete an applied research project to qualify for tenure. Projects usually involve external businesses and may include students as well. Applied research is a way for KEA to ensure that teachers have up-to-date knowledge of businesses and hone their skills in research, while providing new input for students in the school's teaching.

KEA conducts applied research related to the school's four areas of education: construction, digital, design, and technical. All projects must be related to technology, sustainability, and business, but beyond that, the scope is

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broad. For example, KEA has carried out projects on digital applications for patients with incontinence, screen technology in elderly care homes, analysis of the sustainability of work uniforms, and on the social responsibility of user experience designers and web designers.

This report explains KEA's general structure of and approach to applied research and exemplifies this with a specific case of applied research, the Green Code project. Although KEA is not a vocational education and training (VET) provider, KEA's approach to applied research may well be relevant to VET providers and could be imitated elsewhere.

1.1 The Green Code project

This report uses the Green Code project to exemplify how applied research may take shape at KEA. The project was formally named Sustainable Web Development and was conducted together with the marketing agency Advice. It revolved around the development of a calculator for the CO2-emission of web pages as a way of helping businesses with the development of more sustainable practices. The project was initiated by one of the teachers at KEA and has subsequently been used as a teaching case twice. The case will be described in greater detail in chapter 4 below.

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2. Management and organisation

Applied research is an integral part of KEA. For teachers to become tenured, they are required to complete a research project, and the findings of the projects are both incorporated into the teaching at KEA and often published. Applied research projects are also a way for teachers to get closer to businesses and learn more about current developments. Once teachers have obtained tenure, they are not required to participate in future applied research projects. Yet, many choose to do so.

KEA conducts applied research within four broad topics: construction, digital, design, and technology (e.g., automation and other state-of-the-art technology) – with the corresponding applied research departments (KEA Build, KEA Digital, KEA Design, and KEA Tech) illustrated in the organisational diagram below. Each of the four applied research areas is governed by an educational council comprising six members from KEA and nine external members, who are appointed by key institutions in the Danish labour market, such as employers' and employees' associations and research institutions. These councils define the broad lines of the research activities at KEA. Within each general research programme, teachers can apply to conduct their individual projects. The projects must be approved by the corresponding head of programme.

At KEA, teachers are the formal project leaders of their own applied research projects, and they are responsible for leading the project, collecting and analysing data, and communicating their findings. But they are not alone. As depicted in figure 2, KEA has a department for research and innovation (KEA Research, Career & Relations), which employs research consultants, who provide methodological and research counselling, and research assistants who help with more administrative tasks related to project management. These functions lift some of the administrative burden off the shoulders of the teachers and ensure a higher quality of research. Some of the projects also involve students in data collection and analysis. The function of the research consultants is explained in detail below.

Organisational structure of KEA

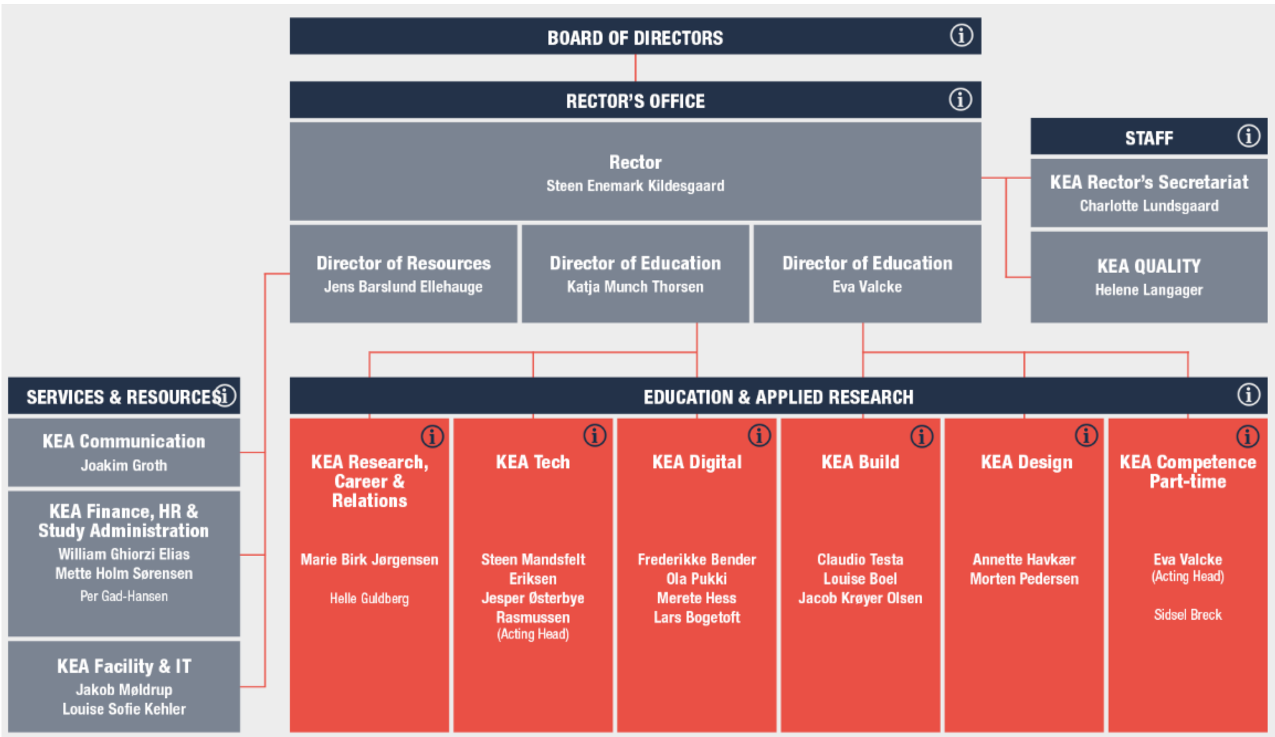

Figure 2: Organisational diagram of KEA. (Source: KEA, n.d.(a))

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2.2 Strategy

As one of its guiding principles, KEA seeks to help businesses make better decisions in the short run, i.e., not too far into the future. This is also the case for applied research projects. They must be oriented towards the needs of businesses and be expected to have an impact in the near future.

Although KEA does not have a designated strategy for its applied research activities, these support the values expressed in KEA's overall mission, which is to educate and upskill active and dynamic (future) employees with practical skills and theoretical insights within design, technology and business. Another cornerstone of KEA's current strategy is the promotion of sustainability, as both KEA employees and students are encouraged to reflect on and design sustainable solutions. This is also evident in the applied research projects, as relevant collaborations with external partners are expected to have some degree of sustainability perspective (KEA, n.d.(b)).

Regarding the Green Code project specifically, the focus was related to a wider agenda of sustainability in web design, which has become an important topic following Tom Greenwood's publishing of *Sustainable web design* in 2021 (Greenwood, 2021).

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3. Resources

3.1 Centre for Research and Innovation

Besides the teachers who lead and conduct applied research projects, the most important resource for applied research projects at KEA is the Centre for Research and Innovation (KEA Research, Career & Relations in the organogram in section 2.1) along with the research consultants and research assistants formally attached to it. In practice, these research assistants and research consultants are associated with one of the four different applied research departments (KEA Tech, KEA Digital, KEA Build, and KEA Design) according to their expertise. Research consultants at KEA all hold PhD degrees and are expected to produce scientific, peer-reviewed publications and stay updated on the research literature of their respective fields. Beyond maintaining their own skills in research, their main task is to support teachers in their applied research projects. This happens in multiple ways.

Through their experience with research, the research consultants can provide teachers with methodological feedback on applied research projects. Teachers generally hold master's degrees and are thus not particularly trained in research. Having an experienced researcher assigned to each project, is therefore a great asset in ensuring the scientific validity and overall quality of the project. Research consultants also help teachers structure their projects and communicate the findings of the applied research projects in various media. This can be peer-reviewed journals, but it can also be less scientific sector-related magazines or in podcasts. The more scientific the outlet, the more teachers rely on the research experience of research consultants.

New teachers who are just beginning their research projects require more firm guidance from the research consultants. Here, consultants often point teachers directly towards the data to be collected and the appropriate methods to be used. As teachers grow more confident, they are given greater autonomy in the projects. Although the teacher is always the formal project leader, research consultants tend to take a leading role in the projects. This is simply because teachers rarely have the required professional research experience from the get-go.

The research assistants at the Centre for Research and Innovation play a more administrative role in the projects. However, they are also important since teachers are still required to maintain a high degree of teaching while conducting their applied research projects at KEA.

The library at KEA is also a central resource for teachers and research consultants. Besides providing access to literature, the librarians function as personal assistants, who support teachers throughout their projects by pointing them to relevant literature. Each applied research project has a librarian assigned to it.

Figure 3: The KEA library (Image: KEA)

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3.3 Funding

All teachers who participate in applied research projects are allocated a certain number of hours to work on these. Other research expenses, such as attending conferences, are covered by the relevant programme budget, depending on the subject. Teachers generally do not attend new courses as part of their applied research projects.

Some applied research projects receive external funding from Danish foundations or from the Danish business cluster system. This provides resources for KEA to support the projects. Such funding often depends on collaboration with external knowledge institutions, such as universities, and they are generally rare at KEA for two reasons: 1) they are more cumbersome to set up administratively, and 2) they rely on competitive funding, and here, KEA is under pressure from university competition because the universities have a stronger scientific output and weightier credentials.

It is noteworthy that although applied research projects are generally dependent on collaboration with external businesses, there is no funding available for these external partners. There are pros and cons in relation to this. On the positive side, having no economic ties to a given company makes the collaboration much simpler to administrate. It also ensures that only motivated companies participate. On the negative side, since there is no economic incentive for companies, the projects generally receive a lower priority. If a company has commercial deadlines coming up or other commitments, these tend to take precedence over the pro bono applied research project.

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4. Approach to fostering innovation

'Action research' is the fundamental and guiding principle of applied research at KEA. As a method of research, action research involves the simultaneous study of and attempt to solve a specific issue. The approach is, thus, not just analytical, or descriptive. It involves the initiation of concrete solutions (be they material or immaterial) to the problems studied.

At KEA, this double approach permeates applied research as well as teaching in general. The teaching pedagogy relies heavily on cases where students learn while trying to solve a problem for a company. The cases can be imagined by the teacher or provided by actual businesses, the latter working similarly to case competitions, where students have one or two weeks to provide a solution, which is then presented to the company.

There are two kinds of partners for KEA in applied research projects. A partner can be a research institution, such as a university. However, this usually requires external funding and is less common. Projects with businesses are more proliferate, and these generally rely on personal relations and network rather than formalised partnerships with external funding involved.

For students, participating in projects with companies makes the teaching and the exercises more realistic and closer to the actual job market. The assignments help students put their academic and theoretical skills into practice.

4.1 Green Code – Project background and assignment

The Green Code project was initiated by a teacher at KEA, who heard a presentation on sustainable web design by the marketing company Advice. The topic was a good fit with KEA, because it was relevant to students in the multimedia design programme and within the field of sustainability. The teacher reached out to Advice, and they agreed to initiate a project.

This was not the first interaction between KEA and Advice. Advice's employees occasionally give presentations at KEA or participate in external reviews of KEA's programmes. This all provides occasions for networking and the building of personal relations, which may potentially be mobilised in future projects. The management in Advice considers it important and a societal responsibility for their business to contribute to the enhancement of education, and KEA is very receptive of their feedback. Because the collaboration between KEA and Advice is bilateral, the personal chemistry between participating individuals is important.

The applied research project initially revolved around meetings and workshops between Advice employees and teachers at KEA. Advice was then invited to present a case to students in the multimedia programme, who were given a week to develop a solution.

Two factors were important for Advice at the outset: one was that the scope of the project was well-defined, and that Advice knew what was expected from them. The other was that there was a clearly designated project leader from KEA, who was easy to contact. These matters were settled in the initial meetings, where teachers and Advice also settled which IT programmes to use in the project, since this had to fit with the students' curriculum.

In the Green Code project, the assignment was provided and subsequently evaluated by Advice. For students, the project lasted a week. On the first day, Advice gave a general presentation on the topic of sustainability and web development and then presented the assignment. On the final day of the project, students presented their solution to Advice and received feedback.

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Advice presented the assignment in six simple slides presented below. The slides stated the purpose of the solution to be developed, the expected format of the output and the technical specifications of the application programming interface (API).

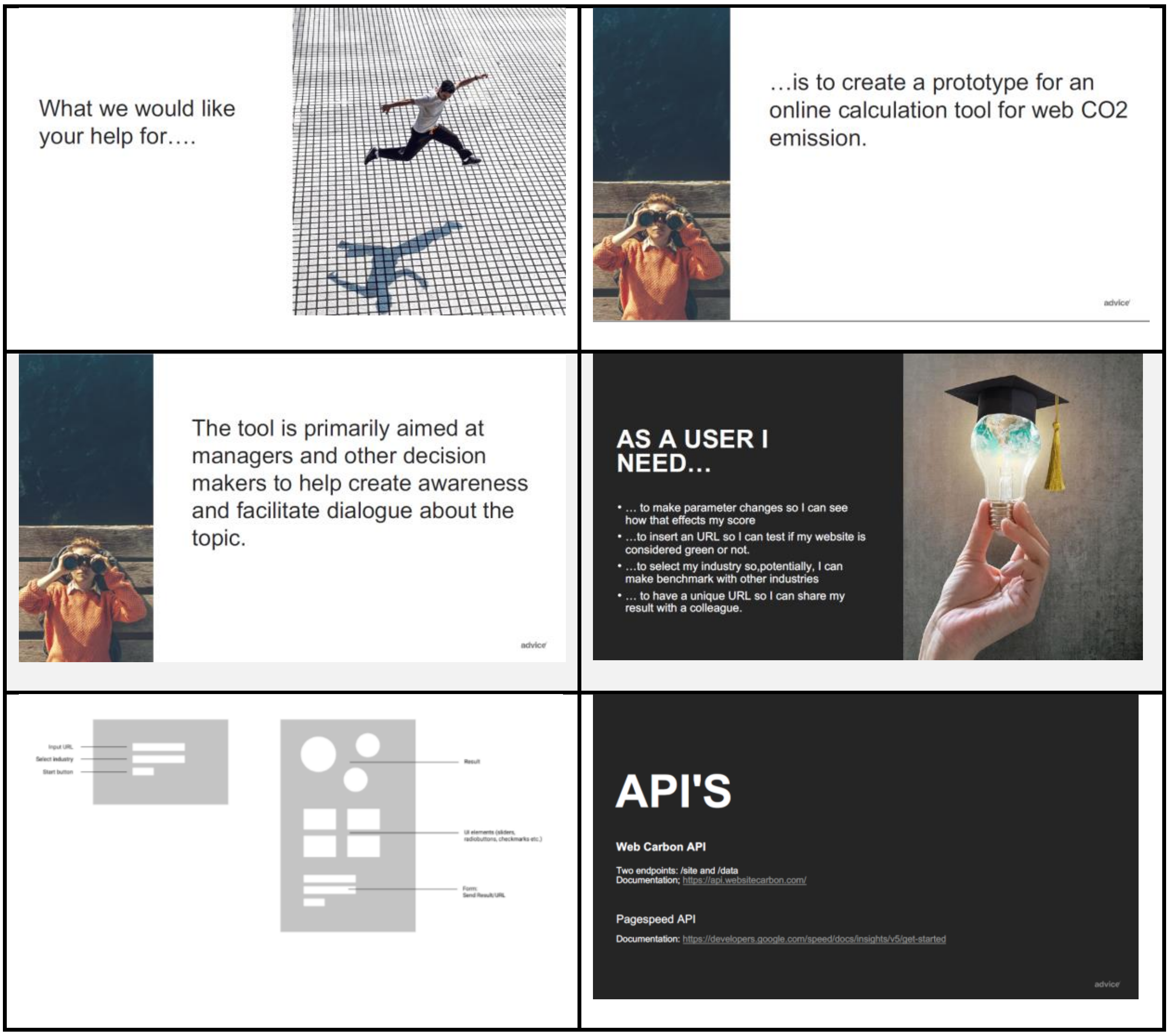

Figure 4: Slides introducing the Green Code assignment. (Source: Advice)

The assignment itself had two elements. First, students had to make a CO2-calculator by using the coding framework React. The calculator measured the energy consumption of webpages by multiplying the features of a given webpage (such as images and videos) with the average amount of energy consumed by such features. For instance, having a looping video on a website requires far more processing power than having still images, and this resolves in greater energy consumption and resulting CO2-emissions.

Secondly, students had to visualise the CO2-emissions in a way that would support dialogue between Advice and a hypothetical client. In other words, they had to show how much CO2 was emitted by different web designs. One group of students did this by comparing the volume of CO2 emitted by the website in a year to the size of an average person on a horse (see figure 5 below).

This second stage of the project was vital, because the purpose of the CO2-calculator was to facilitate a dialogue on sustainability between the web developer (Advice) and prospective clients, who tend to not think about sustainability when making choices about web design. Students were given a large degree of freedom for this second part of the assignment in order to come up with creative results. The point was to help students think about data visualisation in a way that was conducive to customer-dialogue and could help get a message on the

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environmental impact of a website across in an intuitive way. The project with Advice was subsequently repeated with new students the following year.

```
function calculate(e) {
  e.preventDefault();
  const nextData = [];

  //* calculating total hours and minutes on the apps *//

  let instagramYearly =
    parseInt(theForm.current.elements.instagram.value) * 365;
  let instagramCo2 = instagramYearly * 1.05;
  if (instagramYearly > 0) {
    nextData.push({
      name: "instagram",
      time: minutesToHours(instagramYearly),
      amount: gramsToKilos(instagramCo2),
    });
  } else {
    instagramYearly = 0;
    instagramCo2 = 0;
  }
  props.setInstaInput(theForm.current.elements.instagram.value);
```

Figure 5: Screenshots provided by a student who worked on the Green Code assignment.

4.2 Learning and dissemination at KEA

The findings of applied research projects at KEA can be disseminated in different ways. The findings of all projects are integrated into the teaching at KEA, so students benefit from up-to-date insights. A few projects result in academic and peer-reviewed articles. More are written into articles for sector-specific magazines or conference papers. Some projects also result in podcast contributions.

The type of dissemination is voluntary for teachers, so it often depends on the interests and ambitions of the individual teacher. Some teachers focus more on the student outcomes than wider dissemination, and their projects may only result in a LinkedIn post or something similar.

4.3 Green Code: A chance for reflection

Although Advice reports that they were happy to participate in the Green Code project, Advice also reports that they did not gain much new knowledge directly from cooperating with KEA. However, for Advice, the cooperation is a good occasion to structure their own thoughts and experiences related to the topic of sustainability and web design. This benefitted Advice in their future engagements with existing and potential clients, since understanding the green transition and having a clear and thought-through approach to sustainability can be a great selling point and a way to distinguish oneself in the market. The Green Code project may not have provided Advice with a lot of new insights, but it helped them conceptualise and communicate what they already knew.

4.4 Gender and social responsibility in applied research

Gender is not a strategically designated focus area at KEA. However, multiple projects have addressed gender issues. One project revolved around the male-dominated construction sector. Here, students interviewed women working in the sector about their experiences. Gender is also a prominent issue within design and fashion, one of the four main topics of KEA; especially gender-neutral clothes. KEA expects to have more projects on gender in the future. In terms of social responsibility more broadly, an ongoing project addresses social responsibility in relation to web design and user experience. Here, students are challenged to take a critical look at so-called dark patterns or manipulating algorithms that lead people to making decisions that may be socially harmful to themselves or others. Though the project is still under development, the idea is to interview web designing companies about their use of and reflections on such practices.

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5. Impact

5.1 Development of solutions

The applied research projects at KEA usually produce non-material solutions, i.e., knowledge. Often, projects do not provide a direct solution to a business' problem, but instead a new perspective on the issue and why the solution envisioned by this business was perhaps not the most appropriate.

For example, KEA conducted a project on incontinency with a company that wanted to develop a telephone application to benefit patients. KEA conducted group interviews with people suffering from incontinency (predominantly post-pregnant women) and found that the problem for these individuals was not so much technical as it was the taboo surrounding incontinency. They simply had a hard time talking about it. This knowledge changed the perspective and priority of the partnering company.

Another example was a project with a company wanting to probe the market for digital screen solutions in elderly care homes. Here, KEA found that the digital screens were of no interest to the elderly. They simply wanted human interaction. During this process, students learnt that individuals initially assumed to benefit from a given product, may actually have different needs than first assumed. An important lesson learnt for students was to think critically about proposed products and their presumed benefits for specific groups of consumers. When sharing their insights with the business partner, students gained experience in providing feedback and critique through constructive and informed dialogue.

5.2 Learning outcomes

The immediate beneficiaries of the applied research projects at KEA are the teachers and (where applicable) students involved in the projects. Teachers learn about the practices and considerations of businesses, and what they learn is incorporated into their teaching at KEA. For example, teachers learn about the specific IT-programmes used by companies, which can then be taught in classes.

Similarly, when creating and presenting projects to businesses, both teachers and students at KEA hear the feedback from the businesses and learn about their priorities and demands.

Teachers also gain valuable research skills from managing and executing their projects. Further, students involved in projects also gain skills related to obtaining and analysing data, e.g., from interviews, and they get a broader understanding of the research process and the skills it requires. This may motivate students to pursue careers involving research.

For students, collaborating with an actual company tends to be more demanding and stressful than exercises with imagined cases. However, students also report that the experience is more rewarding and motivating – especially if they perceive the company to be truly invested in a given project and issue – as was the case with Advice and the Green Code project. A key takeaway for students is a greater confidence that they have something to offer a business. Having presented their work before an actual company, they become more confident entering the labour market upon graduation.

5.3 Impact on businesses and the wider community

For companies, engaging teachers and students at KEA informs them about new technological possibilities. This is especially the case for less technology-oriented companies that do not have the resources to stay updated on the technological developments within their areas.

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Businesses also gain access to students, who may become future employees. Advice confirms that this is part of what motivates them to engage in projects with KEA. Advice has students from KEA in internships with some student interns having subsequently been employed in full-time positions. It can be added that such career opportunities can help motivate student engagement in applied research projects for companies like Advice. Collaborating with a company helps students build their professional networks, gain valuable contacts, and find professional role models.

Moreover, Advice reports that collaborating with KEA on applied research projects is fun and meaningful. Engaging with students and teachers creates a positive energy in the company and a sense of giving back to the community.

Another project on sustainability was conducted with a Danish amusement company in 2022. The aim was to extend the life of the uniforms worn in the company's amusement parks. The company's internal system was mapped to visualise the flows concerning repairs, internal and external recycling, data collection and the communication to employees – with the aim of guiding the company in prolonging the lifespan of employee uniforms. This resulted in a catalogue of ideas to inspire the development of circular ideas and services, as well as a proposal for future systems aiming at extending the life of the uniforms (KEA, 2022). Overall, applied research projects can be both giving and fun projects for companies and help them move towards more sustainable practices.

The impact is more limited relating to the wider community. As already mentioned, some applied research projects result in podcasts, articles, or conference presentations, but not all. This is mostly dependent on the teachers and research consultants involved in the project.

The project with Advice provided KEA's teachers and students with valuable knowledge about how much energy different web features consume and how websites can be designed to minimise energy consumption. Students also gained new skills in thinking about customer needs and designing solutions for web problems, and their exercised creative thinking about how to communicate and visualise data to a customer.

Through Green Code and other projects related to sustainability, students have also learnt about sustainable practices in web development. They learn that some coding languages generally demand more computing power than others, and that some file formats for pictures etc. are more demanding than others on websites. This enables them to develop websites with a smaller carbon footprint – and to market themselves as professionals with sustainable web development skills.

One teacher reports that students bring these considerations with them to other projects. Students trained in sustainable web practices applied these in subsequent assignments, where sustainability was not a criteria for the assessment of student performance. This shows how sustainable practices become embedded in the students' approach to web design.

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6. Systemic obstacles

This chapter discusses the systemic obstacles for applied research projects as experienced by KEA and by business partner Advice. Three general obstacles have been identified relating respectively to 1) funding, 2) collaboration with businesses and 3) teacher skills.

6.1 Funding

KEA staff reports that financing is a huge obstacle to applied research projects. KEA's own funding for applied research projects is limited, and it is difficult for KEA to obtain external research funding, since, as noted earlier, KEA is often competing with universities with stronger research credentials.

Teachers only have few hours allocated for applied research projects. For instance, in the Green Code project, the managing teacher only had ten dedicated hours per semester. Thus, teachers must take time from their other tasks or use their spare time for applied research projects. Especially for tenured teachers who are not required to participate in applied research, this may lead them to place smaller priority on the projects.

Because applied research is dependent on having a support staff of research consultants and research assistants, KEA (and Danish business academies in general) has to dedicate substantial funding to employing these research profiles – funding which may otherwise have gone into employing more teachers. Applied research is, thus, costly for the organisation.

Since there is no funding available for businesses involved in applied research projects, it may also be a challenge to get businesses to prioritise the projects if they have other deadlines or commitments. Advice reports that they only engage in collaboration with educational institutions when they have enough free time and flexibility. If they have demanding customer deadlines, or the company has employees on parental- or sickness leave, they may not be able to allocate staff resources to such projects.

6.2 Collaboration with businesses

Collaboration between a combined educational and research institution, such as KEA, and a business can also be challenging. For instance, who owns the results from the project, and, more controversially, the data obtained during the project? Here, the two organisations may have a conflict of interest if the terms of collaboration have not been defined clearly from the beginning.

Moreover, the teachers running the applied research projects are generally dependent on the goodwill of the businesses, as they are participating in the project without any monetary compensation. But what happens if a research project leads to findings that are uncomfortable for the company? In such a case, the business may want to avoid having the findings published. Such situations put teachers in a cross-pressure between academic objectivity and research transparency as opposed to maintaining good relations with the external partner.

6.3 Teacher skills

KEA reports a challenge with hiring skilled teachers for the IT programmes. This shortage is present in most of the industry, but the problem is pronounced for KEA, as they are unable to compete with the higher salaries of the private sector.

However, there is also a more general challenge related to the applied research projects. Teachers at KEA generally have master's degrees, but some have shorter educational backgrounds. It is, thus, rare for teachers to be trained researchers with PhDs. The applied research projects revolve around having teachers design and

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execute research projects for which they have not been professionally trained. Moreover, teachers may be more motivated by teaching than by research, which could explain the relatively low volume of research publications from teachers following applied research projects.

The research consultants employed at KEA offer strong support to teachers: they provide guidance and feedback, while also helping to design the applied research projects. Nonetheless, teachers are supposed to be the driving engines behind the projects. And it is difficult to achieve high academic quality and publish results in peer-reviewed journals when projects are driven by untrained researchers.

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7. Conclusion

Applied research is integrated into the organisational structure of KEA. It is part of the politically determined purpose of the organisation and a mandatory element in the career paths for teachers at Danish business academies. KEA has a number of research consultants and research assistants to help teachers develop and execute applied research projects with external businesses, the findings of which can subsequently be integrated into the teachings at KEA, and, thus, benefit KEA's students.

KEA's strategic focus on sustainability carries into its applied research; the Green Code project with Advice is a good example of this. Students were tasked with devising a concrete solution for an external company to calculate the energy consumption of websites and they gained new knowledge of how to think about sustainability in web development and how to communicate such considerations to customers. After being taught about sustainable web development in one project, students at KEA implemented their new green skills in later projects as well, suggesting that they had incorporated the new practices into their general approach to web development.

For KEA students, applied research becomes an avenue for engaging with and learning from businesses and for practicing different aspects of their future profession, such as critical thinking in terms of target group needs and providing constructive feedback to other professionals. Students find it meaningful to work on a project for an actual company that is evaluating their products. It helps students prepare for the labour market and gain confidence in their professional skills.

Most of the applied research at KEA remains dependent on the goodwill of participating external partners, since it is rare to have funding for external partners in the projects. This leaves projects vulnerable to the changing priorities of the businesses, that may not be able to dedicate themselves wholeheartedly to the project. Moreover, teachers at KEA also have limited amounts of time to dedicate to the applied research while having to maintain their teaching as well.

Among the main benefits of the applied research projects are closer interactions between students, teachers and businesses. There is a focus on shared knowledge of current trends and themes for businesses, rather than on research output (article, podcast episode, etc.) of the projects. This is noteworthy, because it suggests that applied research at KEA is less about the academic aspects of research and more about business collaborations in general. Hence, the sometimes-lacking research skills and eagerness to publish research findings among teachers may not be a problem for the learning outcomes altogether.

KEA exemplifies how applied research projects can be used to create value for businesses, teachers and students and to help spur all three groups towards more sustainable practices within their current or future professions. KEA also demonstrates how non-researchers may require substantial professional support from experienced researchers for applied research to be published in academic journals, etc. This taps into a broader political discussion of the role and merits of research-based teaching at business academies, which will not be developed here, except to note that for an organisation to publish its own research and provide teaching based on its own research, substantial investments in research expertise are necessary.

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B. Design Factory at the Singapore Institute of Technology

1. Introduction

This case study focuses on the Design Factory at the Singapore Institute of Technology (SIT) and how it promotes innovation. The Design Factory (DF@SIT) is an integrated part of SIT, which is one of the seven universities in Singapore, and describes itself as 'Singapore's first University of Applied Learning' (SIT, 2023a). The following section offers a brief introduction to SIT and DF@SIT to present the reader with some background information, before diving into the details of the case study.

1.1 Singapore Institute of Technology and its Design Factory

SIT is a publicly funded university in Singapore. Its origins can be traced back to 2009 when it was established (initially under a different name) as part of an initiative to provide polytechnic[1] graduates with more opportunities to obtain recognised higher degrees. Before being formally established as an autonomous university through a parliamentary act in 2014, SIT exclusively offered programmes in collaboration with five international university partners within Engineering, Game Design and Culinary.

Figure 1: The main campus of SIT at Dover Drive, Singapore. (Image: SIT)

Since 2014, SIT has grown significantly. Today, the university offers more than 40 degree programmes (at bachelor's, master's and doctorate level) within a wide range of fields, including Aerospace and Aviation,

[1] Polytechnics in Singapore are tertiary institutions providing hands-on, practice-based learning. Work attachments with industry partners ranging from 6 weeks to 6 months are offered as part of the curriculum. There are currently five polytechnics in Singapore offering education and training programmes at EQF level 5, with some programmes at diploma and post-diploma levels (Ministry of Education Singapore, 2023).

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Chemical Engineering, Design and Media, Food Technology, Nursing, and many more. SIT also provides educational services aimed at professionals, such as professional development courses and workplace learning. While some of the available programmes and courses are offered by SIT alone, others are offered together with international partner universities or exclusively by these partners (with teaching nonetheless taking place at SIT). Currently, the university has around 3,000 students and is spread across one main campus and five satellite campuses. However, work began in 2019 on a new, centralised campus in Punggol, which is meant to bring students, faculty, and industry partners closer together. SIT is expected to move to its new premises in June 2024 (SIT, 2022a; 2023a; 2023b; 2023c).

DF@SIT is one of several innovation centres and applied research centres that have been established at the university to foster closer collaboration with industry.[2] It aims to help students, academic staff as well as public and private clients to apply design-led innovation tools for the creation and piloting of new ideas and solutions. To achieve this, DF@SIT offers a range of services. These include:

- Co-creation and industry mentorship for student-led pre-startup projects
- Design consultancy for businesses, government agencies and other organisations
- Supporting Design Innovation modules (integrated in all SIT undergraduate programmes)
- Facilitation of collaborative innovation projects involving industry partners and SIT students
- Strategy development and business planning
- Training courses and workshops (e.g., for the upskilling of academic staff at SIT)

All the services listed above are anchored in the design thinking methodology that represents the core approach applied at DF@SIT (SIT, 2023d). Briefly summarised, design thinking focuses on finding solutions to problems or challenges through an iterative process that involves several steps. Among these are research activities to map and define a given problem, an ideation stage to develop new solutions as well as the prototyping and testing of these solutions (Interaction Design Foundation, n.d.).

This case study focuses on DF@SIT because its use of design thinking to promote innovation and develop new solutions to real-world problems seems relevant for the Challenger project as a whole. Insights into how DF@SIT supports the facilitation of design modules for around 3,000 students at SIT, for instance, may be valuable in terms of enhancing the innovation capacity of VET. Arguably, this case study could have focused on other innovation or applied research centres at SIT. However, some of these (e.g., the SIT-Polytechnic Innovation Centre of Excellence) actually draw on the innovation capacity of DF@SIT or have a narrower focus on individual technological fields or sectors (e.g., the applied research centres focusing on energy efficiency technology, infrastructure and tunnel engineering, and food production).

[2] See the SIT website (https://www.singaporetech.edu.sg) for additional information on SIT's applied research centres and its innovation centres.

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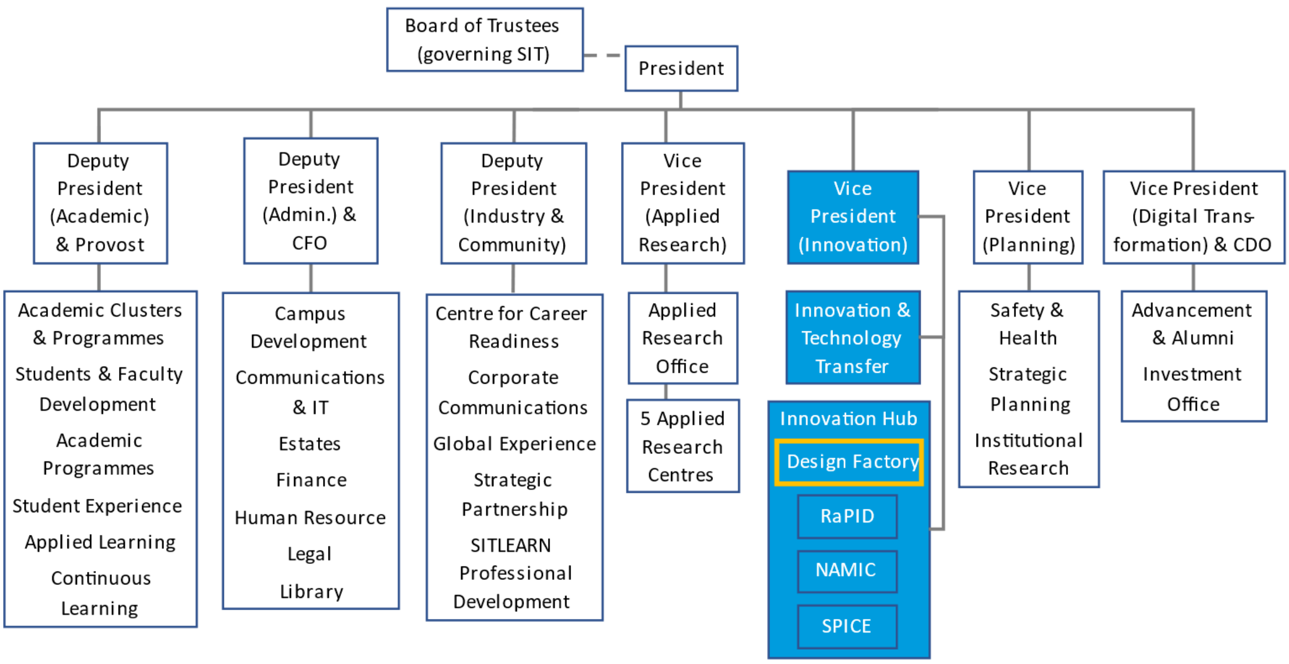
2. Management and organisation

This chapter briefly outlines the organisational structure and management of DF@SIT. It also presents the strategic goals of the university within applied research and innovation, as the innovation centre is meant to align its activities with these.

2.1 Organisational structure

Since 2019, SIT has established five applied research centres as well as an innovation hub (InnoHub) encompassing four synergistic innovation centres. DF@SIT was originally conceived as an applied research centre while today being part of the university's InnoHub, which is placed under the Innovation and Technology Transfer (ITT) division at SIT. This division is headed by the university's Vice President of Innovation as illustrated in the organisational chart of SIT below.

Figure 2: Simplified SIT organisational chart with the Innovation division – including the Design Factory – highlighted.



(Source: Based on internal documents)

Each head of the four centres in the InnoHub reports directly to the Vice President of Innovation. This also goes true for DF@SIT, which itself is headed by an Associate Professor. The Head of DF@SIT has an industrial design background and previous professional experience from healthcare engineering. She estimates to be spending about 30% of her time managing and being involved in DF@SIT activities, while the remainder of her time is dedicated to other obligations, including teaching classes, conducting research, and performing other service duties for the university. Among the main responsibilities of the Head of DF@SIT is the establishment of partnerships between DF@SIT and businesses as well as other relevant organisations. As described in more detail in chapter 3, these networking activities are not only essential for identifying potential clients, but also for ensuring that the innovation centre has access to the human resources needed to implement the full range of its services.

The Head of DF@SIT describes the innovation centre as a strategic university initiative. It is mainly financed through internal funding, while it also creates some revenues as a result of its design consultancy services. The

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three other innovation centres in SIT's InnoHub are RaPID (Rapid Product Innovation and Development Centre), NAMIC (National Additive Manufacturing Innovation Cluster) and SPICE (SIT-Polytechnic Innovation Centre of Excellence). It is the overall goal of the InnoHub to support business partners in their innovation journeys, help the university's academic staff stay in touch with the latest developments in a given industry and to develop graduates that enter the labour market as future value creators and innovators (SIT, 2023e).

2.2 Applied research and innovation goals

In its current mission statement, SIT defines a clear vision for how it wants to maximise the potential of learners and contribute to the economy and society through an integrated applied learning and research approach. In 2024, SIT wants to be:

> *"...a key university in Singapore that lives and breathes industry, with its students and alumni (collectively called SITizens) being thinking tinkerers, lifelong learners and catalysts for transformation who care for the community and stay connected to SIT and their fellow SITizens."*
>
> (SIT, 2023f)

Within applied research and innovation, SIT aims to position itself as a research and innovation hub that is characterised by close collaborations with diverse industry partners. It is the overall goal to support the transformation of Singapore's economy and society by promoting innovation as a means to enhance productivity and workforce development (ibid.).

If one looks back at the services provided by the DF@SIT listed in section 1.1, it becomes clear that the innovation centre's activities are clearly aligned with the described aims within applied research and innovation at SIT.

Furthermore, SIT applied research encompasses so-called translational research and innovation programmes that seek to increase the technology readiness level (TRL)[3] of technological solutions and services in five focus areas. SIT works closely with industry and government agencies to tackle challenges within these five focus areas that have been identified to be of national importance. They include:

- **Community Health Transformation** – The Ministry of Health and private partners have been involved in some of the programme initiatives with a particular focus on older adults, for instance, regarding community care and rehabilitation as well as people-centric dementia care.
- **Sustainable Food Innovation** – SIT is working with industry partners to strengthen Singapore's food security needs and the nutritional needs of an ageing population. For example, by developing plant-based alternative protein foods.
- **Energy Resilience** – SIT engages with government agencies and private partners in the energy sector to help ensure that energy is produced and consumed in a sustainable manner in Singapore in line with the national government's climate ambitions.
- **Sustainable Infrastructure Engineering & Maintenance** – To help ensure that the long-term transport needs of Singapore are met, SIT collaborates with public and private partners in favour of developing and maintaining a resilient and sustainable rail transportation network.

[3] TRL is a metric used to assess the maturity of a technology. It is measured on a scale from 1-9 – from the original idea (Level 1) to the full uptake of a specific product in the marketplace (Level 9).

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- **Sustainable Maritime Engineering** – SIT also works with public and private partners to advance Singapore's capabilities within ship design, offshore renewable energy as well as other growth areas in the maritime sector where sustainable and innovative solutions are called for.

Across these different focus areas, SIT seeks to utilise what it refers to as horizontal 'Technology Enablers'. More precisely, SIT wants to leverage technologies in five fields: 1) artificial intelligence, 2) cyber-security, 3) augmented/virtual reality, 4) 5G and future communications, and 5) robotics and autonomous systems.

The innovation activities of DF@SIT are meant to support the university's strategy within applied research and innovation by focusing on the same five national focus areas. However, for several reasons DF@SIT has not yet achieved a high level of alignment. According to the Head of DF@SIT, one of the reasons is her professional background in healthcare engineering. A significant part of her professional network is simply made up of contacts within this field which has a bearing on opportunities for collaborations and projects outside of the healthcare sector. Further, the innovation centre is only operating in its third year and is not yet widely known (while steadily increasing its reach, for example by partnering with other design consultancies to enhance its scope). Additionally, the Head of DF@SIT is expecting greater opportunities for interdisciplinary collaborations with other applied research and innovation centres, once SIT moves into its new, centralised campus in June 2024.

Last but not least, it can be added that DF@SIT is part of the Design Factory Global Network (DFGN), which brings together 40 nodes based in universities and institutions across 25 countries. The network seeks to bring about change in the world of research and learning through effective problem-solving. It aims to nurture radical innovations based on passion, knowledge sharing and collaborations across cultures and organisations (DFGN, n.d.). The engagement of DF@SIT in this global network is a good example of the outward orientation characterising the innovation centre's activities that are further discussed in chapter 4.

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3. Resources

The following sections describe the different types of resources that are available to DF@SIT and that are needed to implement its activities. This includes human resources, such as the innovation centre's core team and associated contributors, and the facilities and financial resources that these individuals can draw on in their work.

3.1 Human resources

The DF@SIT core team is rather lean and consists of only four members. The Head of the innovation centre has already been mentioned earlier. Next to being responsible for leading DF@SIT, she is also an Associate Professor at the Business, Communication and Design Cluster at the Singapore Institute of Technology. Supporting her is the Deputy Head of the innovation centre with a background in information and communications technology. Next to being Deputy Head of DF@SIT, he teaches in the Infocomm Technology (ICT) cluster at SIT as well as serving as Chair of the ICT Outreach Committee. While the Head of DF@SIT spends around 30 per cent of her working time managing the innovation centre and its activities, the equivalent share is 15 per cent for the Deputy Head.

On this background, only two of the DF@SIT core team members can be described as full-time employees. While they have somewhat different professional backgrounds (one has a degree in industrial design, while the other has trained his design skills in previous job positions), they both carry the title 'creative technologist'. The title refers to their capacities within design thinking and prototyping that they apply in their work to create new solutions and services – often with the help of digital technologies. As described in an article on the DF@SIT website:

> *"Emerging technologies and greater access to information has made it easier for companies to transform their ideas into reality. [...] But the ideation process is just as important as the execution. Companies need more than people who can do repetitive jobs; they need talents who can come up with creative ideas and breathe life into them. This has led to a demand for 'creative technologists'..."*
>
> (SIT, 2022b)

The two creative technologists at DF@SIT are primarily responsible for delivering the innovation centre's various services. They facilitate design sessions for students and faculty members at SIT as well as for external clients. These can take the form of an afternoon workshop or have a longer format and last up to five days. The creative technologists also help businesses or other external clients with developing a new product or service. Supporting clients with the subsequent implementation of newly developed solutions is also a typical part of their consultancy work. Furthermore, the creative technologists are involved in networking activities, for instance with regard to the sharing of knowledge and practices with other Design Factories abroad.

Due to the small size of its core team, DF@SIT is only capable of extending its services more widely by collaborating with a range of faculty colleagues at SIT and with practitioners from different industries. Faculty colleagues – who next to teaching also are tasked with doing a certain level of research each year – work with the innovation centre as principal investigators. They contribute to DF@SIT activities in several ways, for instance, by bringing in new consultancy projects through their professional network. The principal investigators also represent manpower in terms of implementing DF@SIT consultancy projects. They support research and design processes by providing subject matter expertise, acting as liaison with clients and coordinating the possible involvement of students as research assistants. In terms of their background, the principal investigators are faculties from different academic clusters at SIT, such as Engineering, Infocomm Technology as well as Health

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and Social Sciences. According to the Head of DF@SIT, principal investigators do not need to be certified design thinkers. However, it is important that they can scope issues with empathy and are comfortable working in an iterative way to develop solutions that address the needs and requirements of individual users or promote greater sustainability (since DF@SIT is prioritising a design approach that fosters a circular use of resources and environmental care).

To be eligible for and able to work on larger consultancy projects, DF@SIT has entered into a formal agreement on collaboration with an international design consultancy based in Singapore. Because the two parties have defined and agree on a basic framework for their collaborations, they can apply for and get started with projects for clients in an efficient manner.

Finally, the Head of DF@SIT administrates partnerships with around 30 practitioners from different industry sectors with design experience. They help implementing the two design modules that are mandatory for all SIT undergraduate students. While the first module focuses on design thinking theory, the second module is practice-based and challenges students to identify a specific real-world problem and to develop a solution to it. The practitioners associated with DF@SIT contribute to both modules. They help by teaching theory as well as by sharing their professional experience and expertise when supporting students in their practical design projects. These associate faculties have different professional backgrounds with many of them being architects and others interior designers or user interface designers.

3.2 Facilities

DF@SIT is physically located at the SIT campus at Dover Drive. Here, the innovation centre has two dedicated spaces, namely an office for DF@SIT staff as well as a classroom where larger project groups can meet and work. The office can be used by six people at a time. Desks are allocated in a flexible manner with different staff sharing desks and using them at different times. There is a small prototyping area in the office, which Head of DF@SIT describes as a dry lab where prototypes can be developed and tested, for example with the help of computer-based simulations and analysis.

Furthermore, DF@SIT has its own classroom for facilitating workshops and other group activities linked to its design activities, as illustrated below.

Figure 3: Participants at a workshop in the Design Factory classroom. (Image: SIT)

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The classroom can fit at least 40 people quite comfortably and has been equipped with furniture that is meant to ease collaboration, such as movable tables or individual writing pads that can be combined to form different shapes, including a circle for group work. Furthermore, the classroom has an area with armchairs and sofas where smaller groups can huddle and brainstorm or discuss in a more informal setting.

While DF@SIT does not have its own workshop or space dedicated to experimentation or prototype development, staff and students linked to the innovation centre can use other relevant facilities at SIT. These include an SIT makerspace containing different tools and machinery – including 3D printers – that allow users to work with a wide range of materials, such as metals, plastic, textiles and wood. Furthermore, DF@SIT staff and students can get access to engineering laboratories belonging to some of the other innovation centres at SIT with specialised equipment.

It should also be noted that some of the innovation projects at the innovation centre primarily involve the use of digital software or focus on the development of digital solutions – meaning that these projects not necessarily depend on a specific workshop or location but on access to the right digital devices and software.

While facilities and tools for the development of prototypes are essential for the creation of tangible solutions, one of the creative technologists at DF@SIT emphasises that it is equally important for the innovation centre to have a space where individuals can connect and share ideas. Although he and his colleagues regularly facilitate design processes online, for example by using the digital whiteboard application Miro, the creative technologist underlines the benefits of face-to-face interaction in a central design hub. Here, individuals can seek and share information on what kind of resources they can access at different parts of SIT – not only in terms of facilities, but also regarding technicians or specialists with a specific skill set that is needed for a concrete project.

3.3 Financial resources

As a publicly funded university of applied sciences, SIT is mainly financed through grants from the Ministry of Education in Singapore. Some of these funds have been allocated by SIT management to DF@SIT with the Head of the innovation centre pointing out that it is mainly financed through internal funding. This funding has been granted for a five-year period. Renewal of these financial resources will most likely depend on the level and impact of DF@SIT activities in its first five years. In any case, the innovation centre has been tasked to generate as much revenue as possible. While it currently generates some revenue from provided consultancy services, DF@SIT management also has options to seek external funding in the future, for example from philanthropic funds. Considering SIT's forthcoming move to a centralised campus – where it will be easier for SIT faculties and students to make use of DF@SIT services – the innovation centre's management remains quite confident that DF@SIT will also succeed in the longer term. On this background, management does currently not foresee an immediate urgency to seek external funding.

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4. Approach to fostering innovation

This chapter focuses on how DF@SIT contributes to the promotion of innovation skills among SIT students. As described in the following section, the two design modules that are obligatory for all undergraduate students play an important role in this context.

4.1 On the two obligatory design modules

The DF@SIT core team prides itself in working with design-led innovation methods and tools. One of the approaches that is often applied in DF@SIT workshops is the 'double diamond process'. Briefly described, it is an iterative process that guides the individual steps when trying to develop a solution to a specific challenge or problem. The double diamond process is structured around the themes 'discover, define, develop, and deliver'. Individuals using this design approach typically start by discovering a problem and then move on to observing and identifying possible pain points that may be experienced by those facing the problem. Once a problem has been clearly defined in the first stage, it is time to ideate and test plausible solutions[4] (SIT, 2022b).

DF@SIT applies the double diamond approach when working with business clients, and also when helping to nurture innovation skills among students. Undergraduate students are being familiarised with the tool during their participation in the two obligatory design modules. The students first learn about it in theory and subsequently get the chance to apply it in the second design module focusing on identifying and trying to solve a real-life problem. This is possible, because the different faculty staff involved in teaching the design modules are receiving training in design thinking by DF@SIT and, in some instances, also by its previosuly mentioned design consultancy partner. Recently, this consultancy has provided SIT faculty staff with training focusing on circular design in favour of innovation and problem-solving for greater sustainability. According to the Head of DF@SIT, the innovation centre sets aside some of its funding for training purposes. Additionally, faculty staff gain experience and design skills whenever involved in design projects for business clients as principal investigators.

Regardless of what specific method is being applied, all design activities by DF@SIT are directed towards concrete results. As one of the innovation centre's creative technologists emphasises, the focus should always be on helping those trying to find solutions closer to their goal by producing a tangible outcome (be it ideas that can be developed further or specific design concepts).

The focus on developing concrete solutions is evident in the second of the two obligatory design modules. It is therefore relevant to examine, how this practical design module is facilitated and implemented by SIT faculty staff with the help from DF@SIT. Students within an undergraduate programme are first of all tasked with identifying and choosing a problem that they would like to address. This must happen in accordance with some requirements. Most importantly, the problem or issue must be relevant for their studies and future profession. Nursing students, for instance, should identify a problem within health care whereas food technology students should address issues related to food science and/or production.

In the initial stage of the second design module, undergraduate students are grouped into interdisciplinary teams. The groups typically consist of students from different undergraduate programmes in the same academic cluster.

[4] More information on the double diamond process can be found here - https://www.designcouncil.org.uk/our-resources/framework-for-innovation

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Creating such interdisciplinary groups is an administrative challenge, according to the Head of DF@SIT. Nonetheless, an effort is made to ensure that members of the student groups come from at least two different undergraduate programmes. Once they have been established, they are tasked with identifying a relevant problem in a professional setting. For some student groups, this means being briefed about general challenges faced by businesses or other organisations, while other student groups may visit a relevant workplace for up to two weeks and make observations as to what issues could be addressed. On this background, it can be pointed out that the scope of problems students may work with greatly depends on the partnerships that DF@SIT and the faculty staff, who teach undergraduate programmes, have established with external partners.

Since it is one of the focus points in the project Challenger (that this study is being compiled for), it should be pointed out that DF@SIT has no formal policy or guidelines in relation to ensuring gender-balanced student groups or diversity regarding the problems to address through student group work. However, the Head of DF@SIT underlines that the innovation centre's design approach considers the ethical demension of innovation. Students in the design modules are thus asked to take issues, such as environmental sustainability, diversity, and gender inclusion, into account when trying to develop solutions to a problem.

Once students have chosen a specific problem to work on – and it has been aproved by the responisble teaching staff – they start working on a solution using the design thinking approaches introduced during the first design module. As long as they adress a relevant problem, students have freedom of choice regarding the practical tools that they want to use to create a prototype of their proposed solution. Some students may work exclusively on digital solutions and only use different software applications, while others may choose to create digital plans that are realised using cardboard and glue.

Students themselves describe that working with innovation in the manner described above can be challenging with one interviewed nursing student pointing out that creative thinking and design theory are somewhat removed from the other teachning content in his study programme. However, the student also underlined that he and his peers were given a good introduction to design thinking that teaching staff had adjusted to their level of 'design beginners'. When asked what skills they need to succesfully complete the practical design module, students higlight a range of different skills. These include the ability to think creatively and being open to different perspectives, with one student explaining that the ability to come up with ideas can be stimulated by being open to a wide range of inputs, such as experiences made when taking a walk, reading a book, talking to people or watching films. Furthermore, students underline soft skills needed for collaboration, such as empathy and good communication skills, as essential. This makes sense, partly because the interdisciplinary groups are more likely to reach better results if they manage to draw on the differing perspectives and knowledge of their individual members, and also because passing the module requires a minimum peer grade as group members must formally evaluate each others' contributions.

While learning outcomes for students are described more closely in chapter 5, it can be emphasised here that SIT senior management is focused on providing graduates with the necessary skills to act as intrapreneurs in their future workplace, rather than prioritising the development of entrepreneurs. Described differently, SIT management particularly wants to develop graduates that can bring added value to companies and other organisations by making use of their design and innovation skills when working as employees within existing organisational structures.

4.2 Mentoring of student-led innovation projects

Even though it is not a priority for SIT management to have graduates establish their own businesses, DF@SIT provides mentorship and industry support to student-led innovation projects that may lead to the creation of startups. Students who have a specific idea or prototype of a solution and want to turn it into a product can

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contact the innovation centre for advice. They may receive support in different ways. The Head of DF@SIT and the innovation centre's creative technologists can act as mentors in terms of improving the design of a proposed solution – which may include challenging the student to reconsider whether a proposed solution actually addresses the problem in focus. Students can also be referred to industry contacts by DF@STI staff, which enables them to access the expertise of practitioners in relevant industries and sectors.

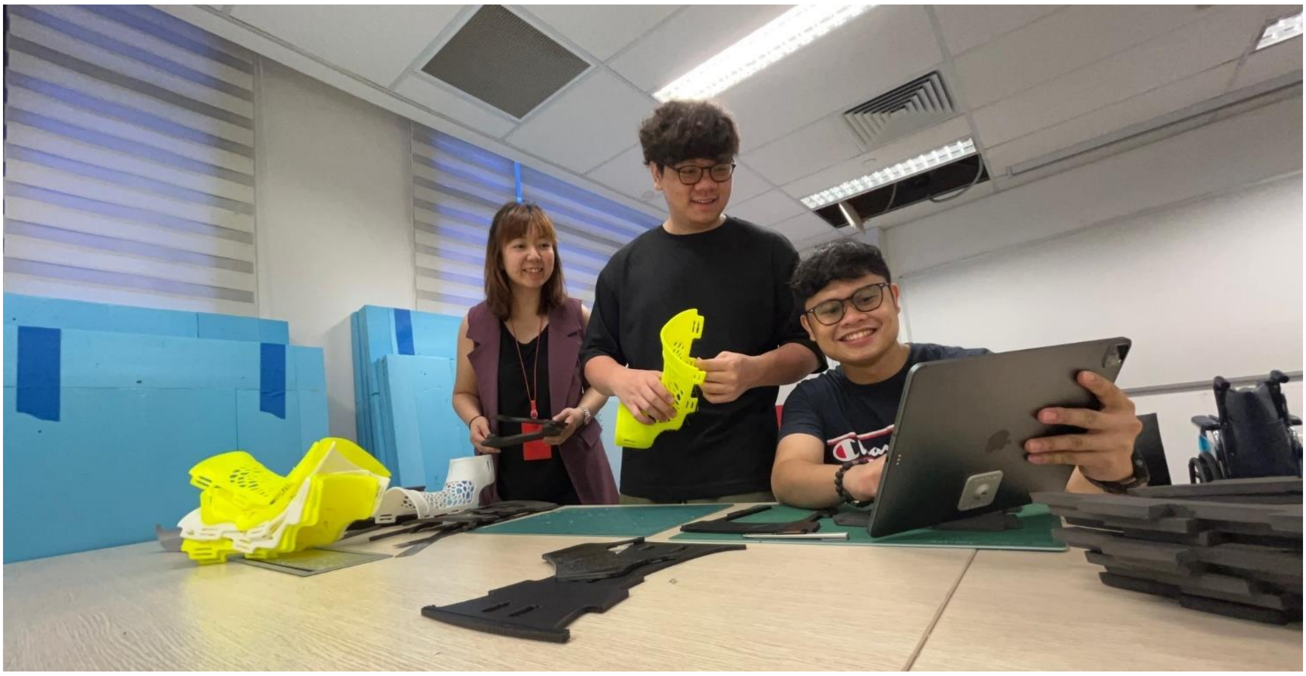

Figure 4: Supporting the production of prototypes is one of the services offered to students by DF@SIT. (Image: SIT)

At the moment, DF@SIT is only providing mentorship to student-led projects at the pre-startup level, while DF@SIT management considers establishing a startup hub at the new SIT campus in the future. Until now, the innovation centre has provided advice to student projects focusing on products in the realm of digital infotainment and healthcare. According to the Head of DF@SIT, there is currently no formal approach to progressing students from completing design modules and creating their 'first solution' to initiating their own innovation projects.

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5. Impact of innovation activities

The following section presents examples of projects led by DF@SIT as well as of innovation projects that were part of the practical design module described above. Together with a description of learning outcomes for students, the presented examples give an impression of the impact that DF@SIT innovation activities have had so far.

5.1 Selected innovation projects and their learning outcomes

DF@SIT has provided design consultancy services for a wide range of clients. One specific example was a project for the National Council for Social Service in Singapore (NCSS). It entailed the facilitation of online design activities over a period of five days dispersed across one month. Participants of the activities were social service workers that act as 'volunteer managers'. This means that they are responsible for matching individuals from private companies that want to do voluntary work, for instance as part of the companies Corporate Social Responsibility (CSR) efforts, with social agencies that need additional hands. The task can typically be a significant administrative challenge, since some corporate volunteers only are available during the weekend, others only in the evening, etc. With the help of design facilitation by DF@SIT, social service workers from the NCSS were able to develop ideas for specific tools that could be used for planning and matching the requirements of corporate volunteers with the needs of social agencies. The creative technologist of the innovation centre, who was involved in the project, expressed confidence that some of the developed solutions may soon be integrated into relevant government websites and thus help with the distribution of volunteers in Singapore's social services.

Another DF@SIT project for a professional client involved the development of a solution to a specific problem within logistics. Important background information for the project was that Singapore experienced an increased need for storing vaccines and medication as well as essential food supplies during the Covid-19 pandemic, following a heightened awareness of possible disruptions to supply chains. In this context, DF@SIT worked with a logistics warehousing company to create a modular cold storage box for keeping items at low temperatures. The developed design allowed for easy assembly of the storage box by two people and thus represented a flexible solution for storing fragile supplies in warehouses that are not climate-controlled (SIT, 2022b).

In terms of helping to facilitate innovation projects by students, DF@SIT has also had a clear impact. This can be illustrated with the help of a specific example. A group of students from the Health and Social Sciences cluster (mainly nursing students) was tasked to visit and help out in an elderly care home in a high-rise building. During their stay, the students were meant to observe what problems the residents and/or care staff were facing before selecting one to address in their design project. After several brainstorms and discussions, the group decided to focus on the problem that the wheelchairs of residents were typically left without order in a hallway where they were taking up a lot of space and blocking people from passing. The student group went on to develop ideas for how to solve this issue, ending up with an idea for a wheelchair rack. Once the students had settled on this idea, they needed to explore ways and tools for creating a prototype. Using an autodidactic approach, some group members created digital designs in a dedicated software application. Although the students had access to a makerspace, they decided to create their prototype by hand, using cardboard. According to one of the involved students, participation in the design project had a range of positive learning outcomes. He describes to have honed his observation skills, to have picked up 3D design skills, while also having benefited from the different perspectives in the interdisciplinary student team. The images in figure 5 below illustrate the described design process.

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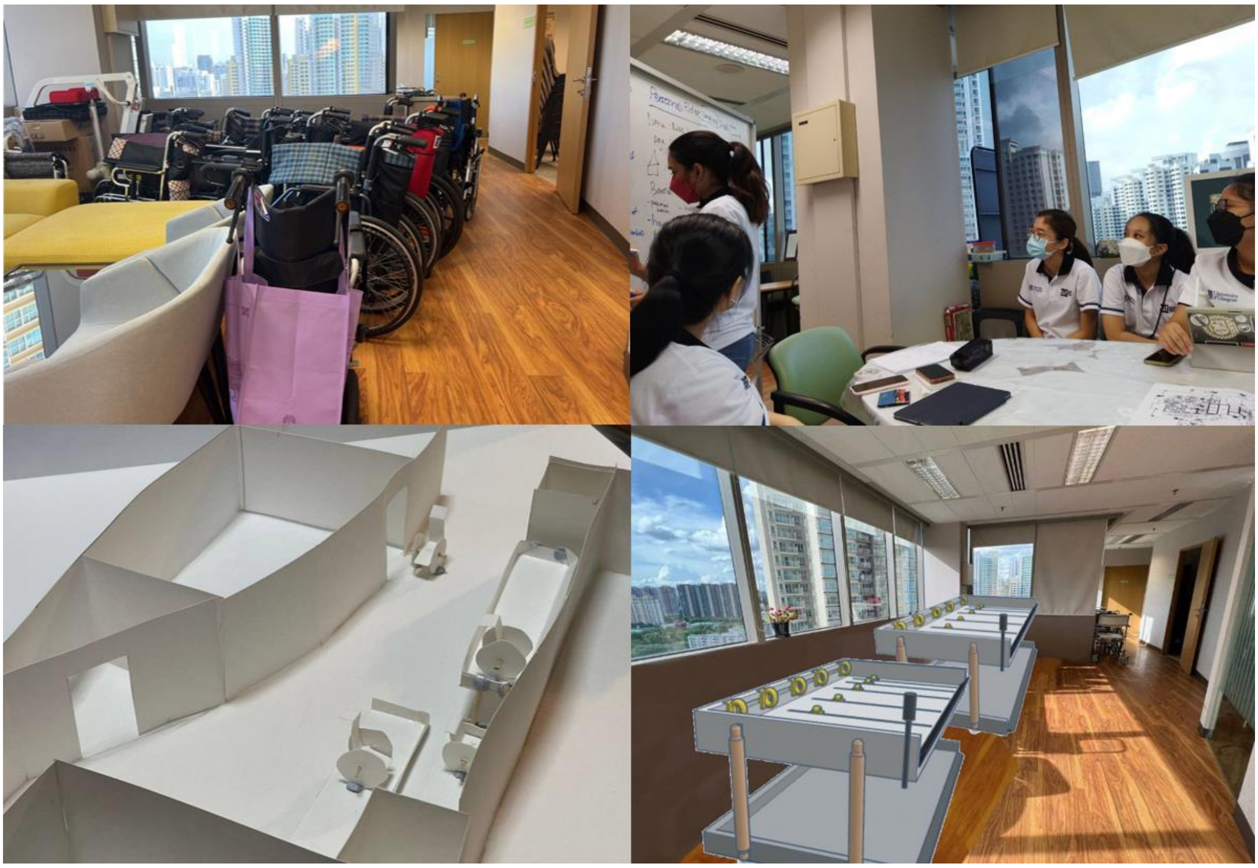

Figure 4: Clockwise from above left. 1) Wheelchairs in the elderly care home; 2) Students during group; 3) the 3D- designed prototype in an edited image of the space used for storing wheel chairs; 4) card board minitiare of the space and the wheel chair rack proposed as a solution by students. (Images: Shared by the student project group)

Other examples of innovation projects in the context of the practical design module include efforts by students from the academic cluster Business, Communication and Design. They were tasked to produce marketing videos for a SIT business partner. One student group – consisting of undergraduate students in Accountancy as well as Digital Communications and Integrated Media – worked with both analytical software to develop a communication strategy and professional video equipment to produce an audiovisual advertisement. The business partner was pleased with the results of the student-led design projects and chose to show marketing material produced by students on a public display hanging on the facade of a large building. One of the students who had his work shared in this way pointed out that it increases his motivation to work on a design project when it is done for and appreciated by an actual client. He also underlined that working on a case like this enables him to be in contact with industry professionals and to gain experience with the tools and equipment that he expects to work with in his future career.

DF@SIT also hopes to promote contact between students and businesses by arranging an Industry Day in the end of the trimester during which the practical design module is being taught. On this day, industry partners are invited to meet students who get the possibility to showcase the results of their design projects. Last but not least, it can be added that it is a general approach at SIT to prepare students for professional life by exposing them to industry experiences. For instance, through the so-called Integrative Work Study Programme, which is an obligatory feauture of all SIT degree programmes, students will undertake at least eight (and up to 12) months of relevant work within the course of their studies. The close relations between SIT and industry are also reflected in the fact that former graduates have gotten in touch and connected colleagus or other organisations in their professional network with DF@SIT.

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6. Systemic enablers and obstacles

There are several factors that make it possible for DF@SIT to provide its services and successfully promote design and innovation skills among SIT students. Among the most significant factors are government efforts to promote design as a tool for change and economic growth. In 2003, the Design Singapore Council was established as the national agency that promotes design and in 2015, Singapore was designated as a UNESCO Creative City of Design. Today, the national design agency is placed under the Singapore Economic Development Board (Design Singapore Council, n.d.). This governmental championing of design to promote innovation has created an awareness of and openness to design in many sectors, according to the Head of DF@SIT.

Furthermore, DF@SIT management underlines that partnerships between public and private organisations are very common in Singapore and relatively easy to establish since, for instance, public institutions and businesses can clearly see the benefits of collaborating with each other. This is helpful for the innovation centre – both in terms of partnering with a design consultancy on projects for clients and in terms of establishing partnerships with businesses for educational purposes. Additionally, the Head of DF@SIT points out that the design community in Singapore is rather small, meaning that most involved stakeholders know each other, making it easier to find and access relevant expertise when needed. As previously mentioned, DF@SIT benefits clearly from working with a design consultancy. They enable the innovation centre to take on bigger projects for clients and also provide design training to SIT faculties. At the same time, the consultancy partner gains access to academic expertise which strengthens their own attractiveness to potential clients.

Despite of the above, the DF@SIT core team also experiences challenges and obstacles in their work. In terms of consultancy services, they point out that issues can arise in relation to intellectual property rights. Since SIT management is interested in securing at least some of the legal rights to utilise and benefit from results of design consultancy projects, it can be difficult to reach feasible agreements with business clients.

In terms of facilitating the practical design module, a particular challenge is the need for different equipment by different study programmes. Currently, DF@SIT is addressing this issue by collaborating with and using equipment from the various centres focusing on innovation and applied research at SIT. This approach is also taken when offering pre-startup mentorship to students with their own innovation projects.

Another enabling factor is the willingness of DF@SIT staff to guide students – both those working on extracurricular projects and those working on group projects within a study programme – outside of regular hours. The Head of DF@SIT is willing to make herself available for student advice during evenings and at times also during the weekend and is quite confident that the majority of teaching staff are also willing to 'go the extra mile for students'.

Further, it was mentioned in section 3.1 how the Design Factory and SIT more widely ensure that teaching staff have industry insights and knowledge of the latest technologies and approaches applied. This is achieved by having practitioners come in as part-time teachers. A significant challenge in this context, however, is to establish and maintain relations to enough practitioners with backgrounds of relevance for the different study programmes at SIT.

Finally, the DF@SIT core team is aware that more must be done to spread awareness of the different services and opportunities for collaboration that the innovation centre offers among students and faculty staff at SIT. For instance, according to the Head of DF@SIT, there are colleagues at STI who believe that the Design Factory is a special interest group. Therefore, the management of the innovation centre aims to increase internal knowledge of DF@SIT to ensure that the innovation centre plays a more prominent role once SIT moves into its centralised campus in 2024.

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7. Conclusion

The Design Factory at the Singapore Institute of Technology is a strategic initiative of the university's management and financed primarily through internal funding. As an innovation centre, DF@SIT fosters innovation through a range of services. These include design consultancy services for business clients as well as the provision of training in design approaches for educational staff and the facilitation of theoretical and practical design modules for undergraduate students. All services provided by DF@SIT are anchored in design thinking with the innovation centre's core team – comprised of a Head, a Deputy Head, and two creative technologists – promoting an ethical approach to innovation that takes matters of environmental and social sustainability into consideration.

DF@SIT activities are in line with the overall strategic goal of SIT, which focuses on maximising the potential of learners to contribute to economy and society by exposing them to industry experiences and an applied learning approach. This strategic focus is reflected in the implementation of the obligatory practical design module as well as the Integrative Work Study Programme that is part of all SIT degree programmes.

Although the DF@SIT core team is small, the innovation centre is able to provide its services through close partnerships with internal and external partners. DF@SIT collaborates with SIT academic staff who act as principal investigators and conduct research within design consultancy projects for clients. The innovation centre also has a close partnership with a design consultancy firm that enables DF@SIT to work on larger design projects for clients. This industry partner offers additional manpower and broader consultancy experience, while also providing upskilling of SIT faculty staff in design methodologies. Furthermore, DF@SIT works with practitioners from different industries who take on teaching responsibilities in the context of the two design modules that are part of all undergraduate programmes at SIT.

The sharing of resources and equipment with other innovation centres and centres for applied research at the university is essential for enabling DF@SIT to help students from different study programmes with their design projects – be they part of extracurricular activities or obligatory innovation efforts. Currently, DF@SIT is physically located on one of SIT's five satellite campuses and, in relation to facilities, has an office and a regular classroom as own spaces for activities. Along with all other faculties and organisational units, the innovation centre is set to move into a new centralised SIT campus in Punggol in 2024. Although it is currently not sure what facilities the innovation centre will have there, DF@SIT management aims to play a more central role in promoting collaborations focusing on design and innovation across the university once the move has been completed.

In addition to limited knowledge of the innovation centre and its services among SIT students and faculty staff, the DF@SIT core team identifies several challenges to the implementation of its activities. These include issues concerning intellectual property rights in the context of design consultancy projects for clients and administrative burdens regarding the identification and coordination of needed external partners, such as practitioners from different industries that can contribute with part-time teaching. At the same time, DF@SIT management emphasises several factors that enable and support the centre's design and innovation activities, such as an openness to public-private partnerships and a general awareness of design as a motor for innovation in Singapore.

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C. Holmesglen Centre for Applied Research and Innovation

1. Introduction

This case study is about Holmesglen Institute, a vocational and higher education institution located in Melbourne, Australia. It focuses particularly on Holmesglen's applied research activities, including its Centre for Applied Research and Innovation. As an educational institution, Holmesglen offers a range of courses across various disciplines, including business and finance, building and construction, community and health sciences, horticulture and environment, and computing and IT.

The courses offered at the institution are at different educational levels. Holmesglen offers both Technical and Further Education (TAFE)[5] programmes and courses (certificate-, diploma-, and advanced diploma programmes), as well as higher education programmes including bachelor's degrees and graduate certificates.

Figure 1: Chadstone Campus housing the Holmesglen Centre for Applied Research and Innovation
(Image: Holmesglen Institute)

Founded in 1982, the institution offers more than 500 different courses to more than 50,000 students and learners. Furthermore, Holmesglen is well-reputed for its strong connection to the industry, which facilitates practical placements, internships, networking opportunities for students and opportunities for conducting applied research and innovation projects. In 2021, Holmesglen won the Industry Collaboration Award at the Victorian Training Awards for the fourth time in five years cementing its position as a leading institution in terms of industry collaboration (Holmesglen, n.d.).

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[5] TAFE (Technical and Further Education) corresponds to vocational education and training.

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During the last years, Holmesglen has put a strategic focus on applied research and innovation. In 2016, the institution established a Centre for Applied Research and Innovation with the aim of supporting the faculties and researchers of the institution in establishing applied research projects.

Support and promotion are among the key functions of the Holmesglen Centre for Applied Research and Innovation. So far, the centre has been a successful resource for Holmesglen in its quest to promote and further the applied research and innovation activities across the institution. Consequently, the Institute is looking to post further resources into the centre during the coming years to expand and develop the culture for applied research and innovation.

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2. Management and organisation

As already mentioned, Holmesglen is an educational institution offering both vocational and higher education programmes. During the last years, strong emphasis has been placed on applied research both across the entire institution and all its faculties.

As a first step towards building experience and a culture for applied research, the Holmesglen Centre for Applied Research and Innovation was established in 2016. Before that, Holmesglen had innovation projects, but they did not always identify them as applied research. Around the same time, a national focus on applied research surged, which led Holmesglen to write up a strategy paper for their goals within this area.

The aim of the strategy was to establish a direction for applied research and innovation for the entire institution with the aim of establishing a sustainable research structure and culture, and to provide the necessary institutional framework for the strategic focus on applied research.

The Centre for Applied Research and Innovation was an important part of the strategy. Currently, Holmesglen has organised their applied research activities and efforts in an umbrella structure, as illustrated in figure 2.

The Holmesglen Centre for Applied Research and Innovation is placed in the middle of the structure and provides support to the faculties and researchers. Applied research projects and activities are managed and led by the faculties themselves. In the outer layer of the figure stand the industry or community partners involved in applied research projects.

Figure 2: Organisational structure and entities involved in applied research at Holmesglen

(Source: Internal documents, Holmesglen)

The fact that faculties and researchers manage relevant activities themselves has meant that some faculties have taken greater steps in applied research than others, and that the supportive role of the centre therefore varies between faculties.

The centre provides both support and direction to the institution's faculties through assisting with the identification of project opportunities, supporting the development and consolidation of industry alliances and partnerships, developing training and mentoring programmes for the researchers, fostering student involvement in applied research projects, and assisting with securing funding for research activities – among other things. The

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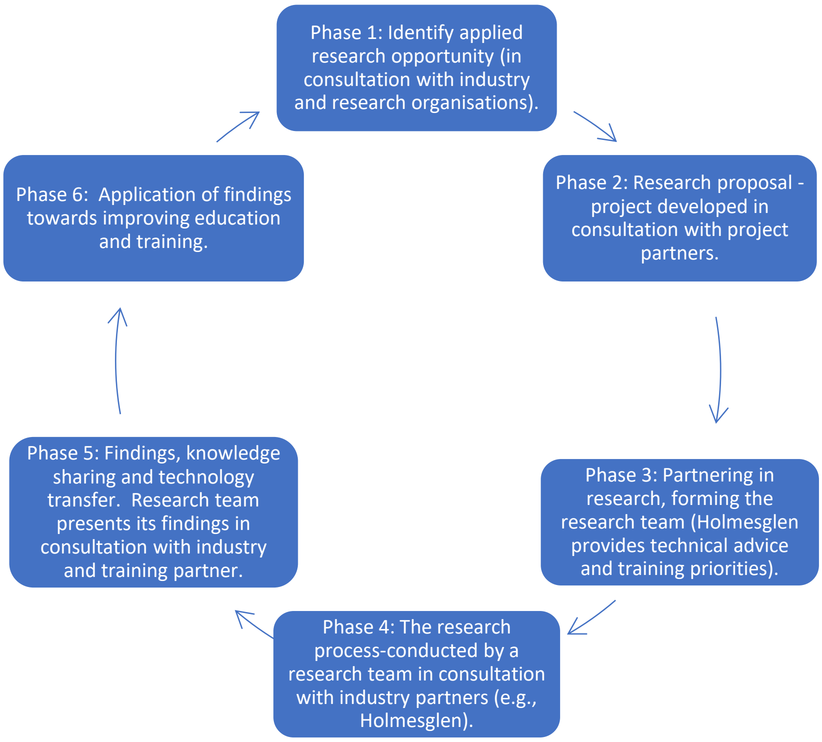
centre also helps arrange speaking and promotion opportunities for the researchers. The centre, therefore, acts as an important driver of Holmesglen's relations with relevant industries and the community.

Besides from the abovementioned tasks, the centre also plays an important role in fostering the development of a culture supporting applied research, which has become a strategic focus of the institution.

As part of the effort to standardise the approach to undertake applied research and innovation, Holmesglen has developed an overview of the typical steps involved in the establishment of an applied research project. The overview is illustrated in figure 3.

Figure 3: Overview of the phases in the approach to applied research projects at Holmesglen



(Source: Internal documents, Holmesglen)

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3. Resources

This chapter presents the resources posted into applied research at Holmesglen Institute, both in terms of human resources and financial resources. Furthermore, Holmesglen's reflections upon the importance of capability building amongst its staff are presented alongside their approach to it.

3.1 Human and financial resources

Since its establishment, the Holmesglen Centre for Applied Research and Innovation's human resources has included the centre's director, Dr Henry Pook, whose position is financed by the Holmesglen Institute itself, and a faculty and administrative structure designed to support the centre.

This means that the faculties of Holmesglen are the main drivers of the specific applied research projects and activities undertaken by Holmesglen. Although the centre offers support and advice, the faculties and researchers are responsible for applying for the funding of their own projects and undertake the management of the specific projects.

Funding for research projects is partly sourced from a range of partnerships with industry, research collaborations with universities, and from the institute itself. Holmesglen's membership of the Building 4.0 Co-operative Research Centre is a case in point.[6] Through a collaborative arrangement with industry, government, and research-based institutions, Holmesglen is able to participate in the formulation and development of innovative research projects designed to modernise the industry sector and its education and training programmes.

This also means that the financing of applied research projects and related activities comes from several different sources. As an institution, Holmesglen does offer some funding that researchers can apply for. At the same time, the institution works in co-operation with industry and other research partners, as well as contributing to building a cooperative research centre.

3.2 Capability building of employees

According to key personnel at Holmesglen, the teachers and researchers are crucial in making applied research work. Therefore, the supportive role of the Holmesglen Centre for Applied Research and Innovation in building the teachers capabilities is highly important.

The Centre for Applied Research and Innovation offers a capability building training programme specifically developed to assist applied researchers to work with industry and formulate and undertake projects. Such capability building has taken the form of conferences, workshops, presentations, mentoring, and individualised support in the preparation of grant applications and formulating proposals for research projects. These workshops have proved highly successful, offering both face-to-face and on-line sessions on topic areas as varied as the responsible conduct of research, human ethics, research questions, project planning, doing literature

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[6] Holmesglen is a partner in a successful industry-led collaborative research bid that secured Commonwealth funding for a Building 4.0 Co-operative Research Centre (CRC). The CRC Programme is the peak funding initiative of the Australian Government for industry-focused research and development (R&D). CRC focuses on medium to long-term industry-led collaborations to develop important new technologies, products, and services, and assist in driving the growth of new industries. CRC grants support medium to long-term industry-led collaborative research for up to 10 years and includes an industry-focused education and training programme to build capability and capacity. CRC participants contribute cash and / or in-kind.

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reviews, research methods, research partnerships with industry, having your work published, the development of an academic article, and getting academic and industry exposure both in scientific journals and at conferences.

Investing time and effort in supporting the development of research skills is an important step towards fostering an applied research culture amongst staff researchers and is a significant contributor to the success of research activities and projects.

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4. Approach to applied research

In this chapter, overall considerations on the teaching philosophy and the pedagogical approach when doing applied research at Holmesglen is addressed along with two specific examples of applied research projects.

4.1 Pedagogical approach

Holmesglen considers applied research as an original investigation directed towards a specific practical aim or objective, such as answering a specific question or solving industry-related problems (e.g., improving on a product or work process) and to apply such efforts in teaching and learning programmes. In other words, applied research is driven by the need for solutions to specific problems and is focussed on outcomes, which is also what sets it apart from basic research.

Dr Sam Duncan, Associate Dean at Holmesglen Institute, explains:

> *"It is the using, doing and testing of research that makes it applied. The outcome must be tangible. It is a very practical way of doing research, as it is not just developing a solution, but also applying it."*
>
> (Source: interview)

The strategic focus on applied research at Holmesglen Institute also means that problem-based learning (PBL) is one pedagogical approach that has been used, mirroring the process of research itself. PBL is an instructional teaching approach that emphasises active engagement and critical thinking by presenting learners with real-world problems to solve. It encourages collaborative problem-solving, inquiry, and self-directed learning, fostering the development of practical skills and deep understanding of concepts.

In general, the Holmesglen Centre for Applied Research and Innovation seeks to encourage an inquiry-based approach to teaching and learning, and in this framework, a range of pedagogical approaches, including PBL, can be considered small-scale applied research.

The pedagogical and didactic approaches vary depending on the particular educational programme and industry. There is not a standardised approach that can be applied across faculties, as it is not the same type of approaches that may be applicable to every industry.

Learners are engaged in a range of applied research and learning activities designed to assist them in gaining the 'hands on' experience necessary to deal with real life challenges and to build a workforce equipped to meet the demands of the 'digital age'.

In the building degree programmes at Holmesglen Institute, PBL has been a mainstay to teaching and learning. The lecturers let learners work in groups to develop a solution to a real-life problem – often coming from a real enterprise. The approach is also used in student capstone projects at the end of a degree programme. Here, students draw upon their previous learnings and group research, to develop a solution to a specific industry problem.

Another example stems from the educational programme of hospitality management. In this programme, the learners undertake applied research for a local tourist association. Small teams of learners align with existing businesses and help them conduct market research, exploring future opportunities and contingencies. In this example, the activities are an integrated part of the educational programme.

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Amongst the skills that learners acquire when working this way are problem-solving and critical thinking. Furthermore, it is paramount that students gain abilities in terms of analysing and evaluating information, considering and evaluating multiple perspectives and evidence, as well as being able to adapt to changing technologies.

Holmesglen Institute is committed to fostering these skills in learners, giving them the relevant tools and methods to solve real-world problems in the workplace, thus, better equipping them to enter a rapidly changing workforce.

Holmesglen's staff experience in industry also allows them to tap into the workflows of the industry, to reflect critically upon relevant challenges, and apply insights gained to their teaching and training programmes. This helps align educational programmes with industry needs.

Figure 4: Facilities at the faculty for Building and Construction (Image: Holmesglen Institute)

4.2 Industry collaborations

Holmesglen Institute maintains good relations with industry partners and has a long track record of industry collaborations in different projects. For instance, Holmesglen has formalised its collaboration with industry through its participation in the Building 4.0 Cooperative research centre (CRC) and its partnership with the Healthscope group of hospitals for health and nursing-based research. These are great forums to approach new potential partners and to keep in touch with new trends and challenges in the industry.

Often, it is in these forums that research ideas are developed, and research questions formulated. However, some ideas and initiatives can also come from the teachers' personal relations and networks with relevant enterprises and other relevant organisations. This is also why it is of great importance, that the teachers and lecturers at Holmesglen are in touch with businesses and industry at all times. Both the researchers from Holmesglen Institute involved in applied research and their external industry partners report that this type of project collaboration is beneficial.

An example of this is a current successful collaboration between Holmesglen's faculty for Horticulture and Environment and the Australian firm Ecology and Restoration Australia.

Textbox 1: Example of an applied research project managed by Holmesglen researchers

Project example 1: Horticulture, conservation and ecosystem management

Many of Australia's endangered birds and mammals are hollow-dependent species, relying on old-growth forests and trees. A large portion of Australia's old-growth forests have been cleared and efforts to revegetate and re-establish many of these hollow-bearing habitats have been hampered by the time it takes for trees to naturally form hollows.

Recent adoption of artificial hollows in younger non-hollow-bearing trees has been a positive development to help overcome the issue. However, longevity has also proven to be an issue with design flaws leading to tree hollow deformities and callus (wound) regrowth over entrances and cavities filling with water.

To further improve the design and suitability of these shelters for hollow-dependent wildlife, the private enterprise Ecology and Restoration Australia has installed 100 newly designed artificial tree hollows.

In a collaborative applied research project, students from Holmesglen will be providing research assistance by monitoring the hollows for occupancy by wildlife. They also receive outside training and certification through a ropes course in tree climbing and canopy access. This is an exciting opportunity for them to acquire additional qualifications and skills, which can be added to the CEM course.

Once trained, the students will be climbing trees in the forest and setting up remote cameras to monitor wildlife inhabiting the hollows, returning every six weeks to change the batteries and SD memory cards. They will also review the camera images and record the data.

Furthermore, the collaboration provides an opportunity for learners to get involved in the work of the industry they will become part of later. An opportunity that would not otherwise have been possible. At the same time, the students get the opportunity to acquire data for the school projects that would otherwise not be possible for them to get their hands on.

Ecology and Restoration Australia has the opportunity to gather more relevant data than what would have been possible if student researchers were not involved. This structure ensures the accumulation of important knowledge that can support the securing of endangered hollow-dependent animal species.

In the project presented in textbox 1 above, Ecology and Restoration Australia provided equipment and other resources for the learners. In return, the involvement of students in the data collection gives the business partner the opportunity to monitor the project progress closely, which is likely to result in improvements for the tested solution.

The resources offered by the consultancy firm are both equipment and formal training, but also support for the learners in formulating their own research projects, making project plans, and preparing spread sheets for the data they collect.

The professor involved in this applied research project reports that the project offers the students unique possibilities to get a taste of the workflow and processes that are followed in their industry. Also, the project provides the students with some very specific non-theoretical skills that are relevant in this kind of job.

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Finally, the project collects data to cover a subject, for which there is currently very little knowledge. This means that the students get the chance to write assignments on and analyse data that would otherwise not be possible.

Altogether, working on this type of applied research project gives a better understanding of how the industry works and how theoretical knowledge from the classroom can be applied in a real setting.

For Ecology and Restoration Australia, working with the Holmesglen's learners has proven to be very satisfying. The involvement of learners means they can make a more thorough data collection, resulting in a better understanding of the challenge at hand. At the end, this means that the firm can contribute with important knowledge to their field.

The consultancy firm, Ecology and Restoration Australia, has also been very pleased with the fact that the project has helped promote the agenda for women in STEM.

Another example is the COIL-project undertaken by the Faculty of Health Sciences and Community Studies. The project was formed in collaboration between Holmesglen Institute and Northwestern Polytechnic in Alberta, Canada. The two educational institutions had an existing partnership, as they had a student exchange arrangement in place, before embarking on the COIL-project.

Textbox 2: Example of an applied research project managed by Holmesglen

Project example 2: The Collaborative Online International Learning project (COIL)

This collaborative applied research project has evaluated the development, implementation, and outcomes of a collaborative online learning programme in nursing education. The project was established between Holmesglen Institute and Northwestern Polytechnic in Alberta, Canada.

In this project, the partners collaborated on building an international nursing education and research parentship applying digital technologies. More specifically, the project was about creating multiple online environments that have facilitated collaboration, sharing of resources, and development and implementation of novel educational and academic experiences for students and faculty staff.

The project was built on the collaborative, online learning pedagogy that was developed by the State University of New York Sunny. It offers meaningful engaging opportunities for students to interact across borders.

During the project, four specific research interventions were developed:

- An online virtual community
- Virtual reality/virtual simulations
- A virtual global classroom
- A virtual community of practice

The virtual simulations included five innovative scenarios.

Among the outcomes of the projects are meaningful and rewarding opportunities for Australian nursing students to engage with Canadian nursing students – regardless of their personal constraints. Also, the project has created culturally rich educational experiences with outcomes showing an increase in cultural and global awareness, a greater preparation to work collaboratively with nurses from another culture, and the development of global leadership competencies.

The COIL project presented in text box 2 won the Holmesglen Institute the Gold Award at the World Federation of Colleges and Polytechnics Awards of Excellence in Montreal, Canada in 2023. This Gold Award also recognised

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the Institute's research on falls prevention in Australian Hospitals (funded by a NHMRC grant), the Integrated Practical Placement programme for learners with disability and the JasperVR simulation for nursing students.

Staff at both project institutions showed great interest in the project, and many faculty members participated with different capacities throughout the project. For the faculty members involved, the COIL-project was a great opportunity to get hands-on experience with doing research. Many of the participating researchers did not hold a PhD, which is why publishing their work was not common practice for them. Thus, the COIL-project has helped the faculty build experience with doing applied research, at the same time building the capabilities of the staff.

Figure 5: Screen shot from virtual reality scenarios developed in the COIL-project

4.3 Building a culture for applied research

One of the most important tasks for the Holmesglen Centre for Applied Research and Innovation is to cultivate an applied research culture. It is a central part of Holmesglen Institute's strategy for applied research as developed in 2015 and 2016:

> *"Holmesglen must also develop a sustainable research culture across all faculties [...] The following steps are integral to the establishment of this culture: identification of current and possible future research effort; the building of a research capability amongst staff; ensuring that adequate support is provided to assist faculties in engaging students across all levels with research and innovation projects; the expansion of industry and community partnerships; and promotion of applied research and innovation."*

(Source: Internal documents[7])

The development of a culture is an ongoing process for Holmesglen, although the institution has already come a long way. As mentioned earlier, Holmesglen has always worked closely with industry on coming up with solutions to industry-related challenges. However, it takes effort to create and disseminate the understanding of applied

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[7] Centre for Applied Research and Innovation, 2016. *Applied Research and Innovation at Holmesglen Institute: Recommendations for Implementation*, (prepared by Dr Henry Pook), p.6

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research, and often it also takes a change of mindset. One part of this is to upskill teachers and researchers to help them take industry collaborations from collaborative projects to actual research (with the potential of outcomes being published in scientific journals).

This is why the Holmesglen Centre for Applied Research and Innovation supports the faculty staff by training and mentoring them in the disciplines and skills that are needed by emerging researchers, who may not have had full exposure to the protocols and requirements of research activity. The centre also encourages more team-based research.

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5. Impact

The Holmesglen Centre for Applied Research and Innovation has been a significant driver of industry-based research and incremental in the development of an applied research culture at Holmesglen. This is evident in the way Holmesglen Institute has developed during the last few years as regards applied research.

Although Holmesglen has not done a systematic assessment of the impact of their efforts, the number of projects undertaken and the number of conferences that the researchers participate in, has increased significantly, with faculties having come a long way in building the skills to undertake more applied research projects.

While Holmesglen has made great improvements over the last year, the development of a culture for applied research is a constant work in progress. The institution is constantly working on furthering the culture and working to encourage the faculties and researchers to take on more projects and to be in continuous contact with the relevant industries.

5.1 Learning outcomes

Resourcing of research projects also includes the utilisation of learners to participate as co-researchers across a range of projects. There is a general understanding at Holmesglen, that the implementation of applied research activities has had great impact on their learning outcomes. Participation in relevant projects is perceived to increase student engagement and further promote skills among learners that Holmesglen otherwise aims to address through curricular activities.

For instance, data on the outcomes of the COIL-project showed that participating learners increased their understanding of cultural differences, while the learners also got the chance to participate in activities, they would not normally participate in. The researchers in COIL experienced that participating learners became more engaged, because they got to mirror themselves in inspiring people from the industry. Similarly, learners in the project acquired rope climbing skills, while active involvement in COIL also gave them an increased sense of ownership over the data they collect and the assignments they work on.

Amongst the general learning outcomes of applied research activities is the acquisition of soft skills, which can be difficult to promote with traditional teaching methods. Collaborating and interacting with industry partners, for instance, helps learners develop their communication and planning skills. Other important skills that applied research helps fostering is the ability to adapt to changing technologies and equipment in the industry as well as to understand the importance of being flexible and curious – as this is considered to be highly relevant in today's fast changing labour market.

Being involved in applied research projects promotes the development of research skills among learners, with project work being a practical way of reinforcing learning. In general, having a strategic focus on applied research has had an impact on learning outcomes in the sense that learners are presented with the latest relevant challenges and technologies of their industry.

Through the participation of learners and lecturers in applied research projects, experiences gained get integrated into approaches to teaching and learning. On this background, the strategic focus on applied research has led to a more practical and up-to-date application of knowledge in education and training programmes at Holmesglen.

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5.2 Capability building

The capacity to undertake applied research differs across Holmesglen's faculties and is supported by the building of staff capability. Generally speaking, Holmesglen's staff has experienced that working on applied research projects can also improve their teaching. Staying up to speed on the latest trends and tendencies of the industry can be hard when you are in a teaching role. Participation in applied research projects is a great way to bring oneself closer to the industry.

It is Holmesglen's belief that building up the teachers' and researchers' capabilities means that they will be more capable of taking on additional applied research projects while being less dependent on support from the Centre for Applied Research and Innovation.

Figure 6: Student involved in hands-on learning (Image: Holmesglen Institute)

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6. Systemic obstacles

Holmesglen has come a long way in building an applied research culture and an organisational structure with a supportive centre that supports the faculties in capability development and other tasks. It can be considered a best practice case in many ways. However, the institution has also face challenges along the way.

As a provider of vocational and higher education, Holmesglen is steadily building its own research structure and broadening its base for conducting research, including greater involvement of learners and institute-based researchers.

One significant challenge is the integration of new, relevant knowledge into established curriculum frameworks. Nevertheless, there is sufficient scope to undertake research-based projects that incorporate assessment of relevant competencies from their training programmes thus allowing the transfer of new knowledge into the curriculum for the benefit of the learners.

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7. Conclusion

Holmesglen Institute has made a strategic decision to focus on applied research and has come a long way during the last eight years. By making a strategic decision and freeing resources to fund the Holmesglen Centre for Applied Research and Innovation, the institute has made great progress in fostering an applied research culture across the different faculties, which has resulted in a growing number of projects and published research as well as increasing speaking opportunities for the institution.

Holmesglen Institute has developed a supportive staff function that supports the capability building of staff on skills related to applied research, but also supports the identification and consolidation of industry partnerships.

The centre supports Holmesglen faculties in their applied research activities and does so in accordance with their individual support needs and research focus.

For Holmesglen Institute, a next step is to develop more tangible goals and objectives, and to strengthen collaborations with industry and community further. These may include the setting of goals for the number of research projects that the institute would like to be implement in the next years, and the setting of targets for how much of the research should go back into the curriculum and benefit teaching and learning at the institution. Finally, and in connection with this, Holmesglen wants to explore further *how* to bring research outcomes into their education and training programmes.

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D. Saskatchewan Polytechnic

1. Introduction

Saskatchewan Polytechnic is a public institution that provides technical education and skills training in Saskatchewan, Canada, with campuses in Moose Jaw, Prince Albert, Regina, and Saskatoon. The institution offers over 150 programmes in various fields, including applied/visual media, aviation, business, community/human services, engineering technology, health services, hospitality/food services, industrial/trades, natural resources, nursing, technology, recreation and tourism, and science. Saskatchewan Polytechnic also provides training to apprentices in several trades. The institution's purpose is to empower a better Saskatchewan by encouraging an economically and socially stronger, more informed, and better prepared community. It has approx. 14,400 students and 1,770 employees.

Saskatchewan Polytechnic's applied research programmes provide practical solutions to real-world problems covering a wide range of fields including agriculture, artificial intelligence, biotechnology, and biomechanics. The programmes are coordinated by Saskatchewan Polytechnic's Office of Applied Research and led by an experienced faculty, which assists in refining research questions, setting up applied research programmes, and building prototypes for testing. The institution's advanced equipment and expertise in dozens of programme areas makes it a valuable resource for research and development. Approx. 160 faculty members and researchers are involved in applied research projects as well as 350 students.[8]

Figure 1: Saskatoon Campus (Image: Saskatchewan Polytechnic)

This case study introduces the management and organisation of an approach to applied research and innovation at Saskatchewan Polytechnic. The study delves into specific examples of applied research projects to showcase their different characteristics and demonstrate the diverse range of approaches to applied research conducted at Saskatchewan Polytechnic.

[8] https://saskpolytech.ca/

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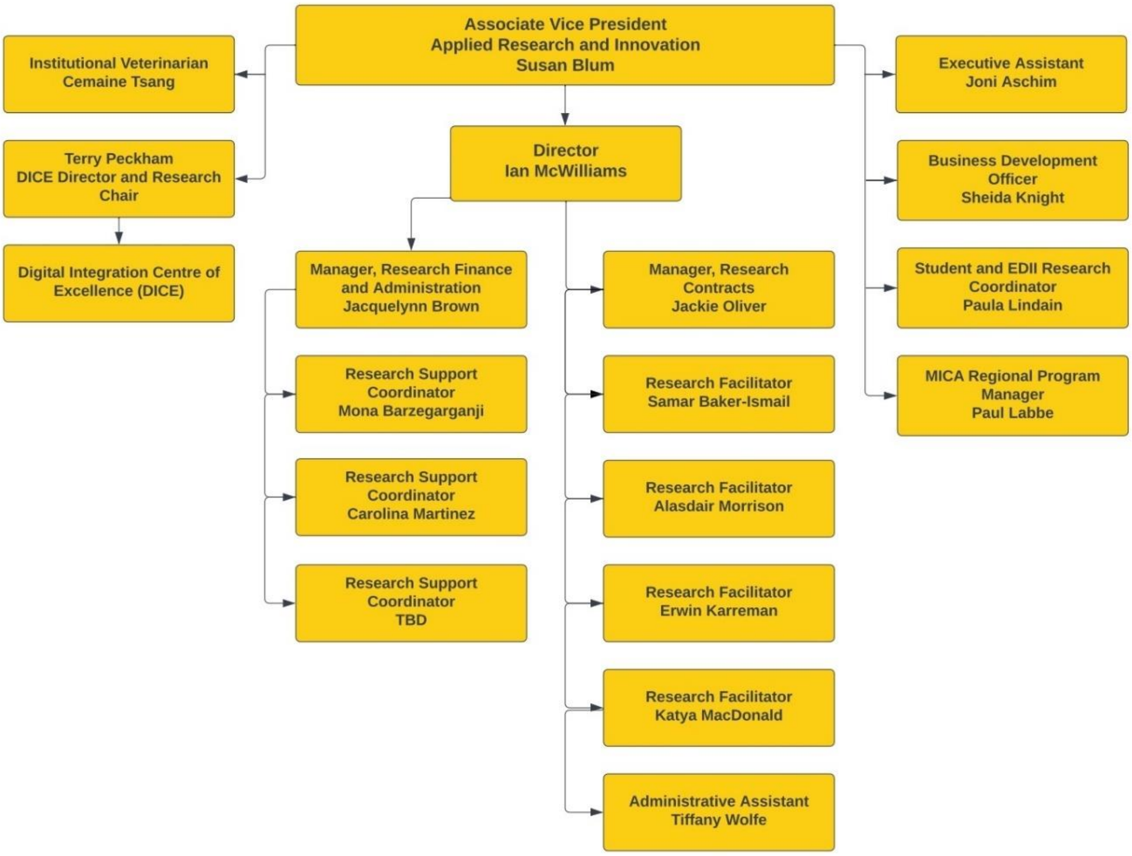
2. Management and organisation of applied research activities

Applied research is a strategic priority at Saskatchewan Polytechnic. In the overall mandate of the institution, it is stated that Saskatchewan Polytechnic "*engages in applied research, drawing on faculty expertise to support innovation by employers, and providing students the opportunity to develop critical thinking skills*" (Saskatchewan Polytechnic, n.d.).

The field of applied research and innovation has experienced significant growth over the past few years, and effective policies and procedures related to research have been implemented. One of the cornerstones of the management and organisation of the applied research programmes is the Office of Applied Research and Innovation. The office is headed by an associate vice president and is responsible for several functions supporting the applied research programmes, like business development, contracts, finance, etc., as illustrated in the organisational chart below:

Figure 2: Office of Applied Research and Innovation – organisational chart



The head of the office, Dr. Susan Blum, describes the role of the office like this:

> *"The office is the touchpoint for industry to engage with us on the various services we can offer. It's here where the journey into innovation begins. The process is a simple one. If you're a business with an idea that needs to be tested or a problem that needs to be solved, they can work with you*

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to see what Saskatchewan Polytechnic can do to help. It starts with a meeting to determine what the partner needs and what our faculty members, students and research centres can offer. We work with businesses of all sizes, from startup to multinational."

(Industry West Magazine, 2023)

The applied research programmes are organised within centres. Each centre aims to bring together experts from various fields. One example is the Sustainability-Led Integrated Centres of Excellence (SLICE) bringing together experts from bioscience, additive manufacturing, energy, agriculture, and forestry to collaborate on sustainability-related projects. The figure below presents an overview of the current applied research centres.

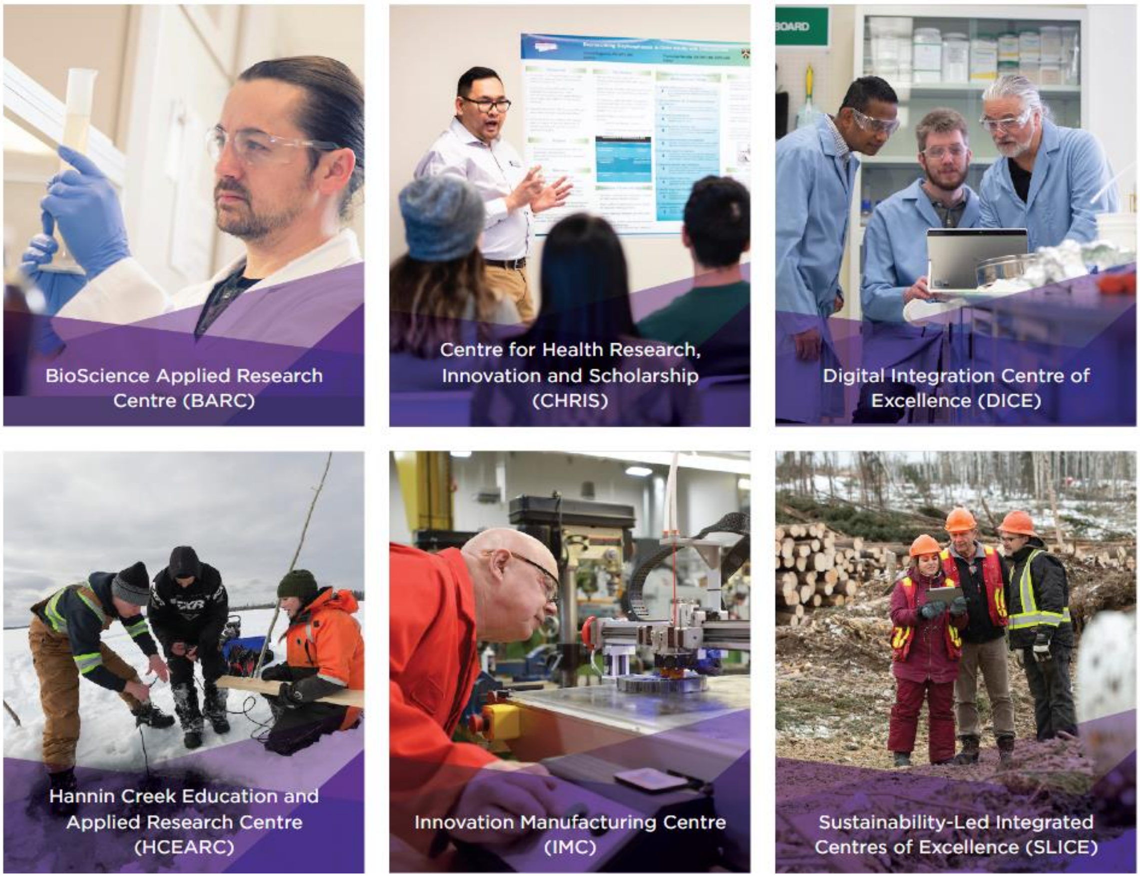

Figure 3: Overview of applied research centres at Saskatchewan Polytechnic.
(Image: Saskatchewan Polytechnic)

- **BARC** offers industrial support through applied research projects within agricultural bioscience, analytical chemistry, analytical instrumentation, biochemistry, microbiology and molecular biology.
- **CHRIS** is the applied research centre within nursing, healthcare and health sciences.
- **DICE** works with industry partners on data challenges with a particular focus on asset management and monitoring; cybersecurity, Internet of Things, time-sensitive networking and mesh communication and control.
- **HCEARC** works with natural resources and protection.
- **IMC** works with improvement of production methods and materials within a broad range of industries and sectors, including agriculture, mining, textile, forestry, food processing.
- **SLICE** works with sustainable resource optimisation and circular economy within agriculture, energy and resources, forestry and manufacturing.

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The strategies and aims for innovation and applied research efforts at Saskatchewan Polytechnic are multifaceted. A key priority is to be positioned as an integral part of Saskatchewan's innovation ecosystem supporting regional economic strongholds like agriculture, mining, forestry oil and gas. However, the engagement in applied research projects also benefits the researchers involved by keeping them up to speed with technical developments and industrial needs. Furthermore, applied research projects increase the employability of the students involved through practical experiences and network opportunities with employers. As stated in the annual report:

> *"Saskatchewan Polytechnic aims to engage in applied research and scholarship to better meet the needs of learners, employers and communities and to support sustainable economic and social development in the province."*

(Saskatchewan Polytechnic, 2022).

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3. Resources

The following sections describe the different resources available to support the applied research activities. This includes the physical environment and facilities, human resources, and financing.

3.1 Physical environment and facilities

One of the key strengths of Saskatchewan Polytechnic's applied research is that industrial partners gain access to state-of-the-art facilities on the four campuses in Moose Jaw, Prince Albert, Regina, and Saskatoon. These facilities include laboratories and advanced equipment such as 3D printing facilities, robots, and cobots. The specific type of facilities available may vary depending on the focus of the applied research centre.

An example of a facility is the Innovative Manufacturing Centre (IMC), which allows manufacturers to access the latest tools, equipment, and expertise to improve production methods and test new ideas. For instance, they can experiment with bioplastics to create lighter, stronger, and more environmentally friendly components for their products. The facilities within the IMC include the Biomaterials Testing and Prototyping (B-TAP) facility, the Research, Additive Manufacturing and Prototyping (RAMP) facility, and Robotics and Mechatronics. Another example is BARC, offering a range of analytical instrumentation, including GC-MS (Triple Quad), ICP-MS (Triple Quad), Ion Chromatography, HPLC, Capillary Electrophoresis, and Atomic Absorption Spectroscopy. The centre also provides resources for library construction, image analysis, and enzyme kinetics. The facility has capacity for plant tissue culture, equipped with laminar flow hoods, media preparation areas, tissue culture cabinets, a biofermentor, and plant growth facilities. For cell culture, it offers biosafety cabinets, incubators, and cryopreservation. Cutting-edge equipment is available for use within the field of molecular biology, such as isolation, quantisation, and analysis of DNA, RNA and protein. BARC also supports research analysis and documentation with image analysis equipment, data integration software, and electronic laboratory notebook documentation. Additionally, it has a microbiology capacity that includes a Biosafety Level 2 laboratory with media preparation and sterilisation areas, fermenters, microscopy, and incubators.

Figure 4: Bioremediation lab (Image: Saskatchewan Polytechnic)

Industrial partners can easily obtain an overview of the available facilities, and the types of challenges the centre typically engages in, by visiting the website of each applied research centre (Saskatchewan Polytechnic, 2023).

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3.2 Human resources

In addition to gaining access to top-notch facilities and equipment, industrial partners collaborating with Saskatchewan Polytechnic also benefit from the expertise of researchers, faculty members, and students involved in applied research projects. To oversee these research endeavours, dedicated research chairs have been appointed, each leading a specific applied research area. Working alongside them are research managers and associates, forming the core applied research staff responsible for coordinating with business partners and providing supervision to participating students.

It is important to note that the researchers at Saskatchewan Polytechnic do not run independent research programmes. They focus on addressing problems, offering solutions, or developing prototypes based on the specific requirements of industry partners. In cases where a research project calls for specialised expertise, the research centres can involve faculty members. However, such involvement necessitates authorisation from the dean and the faculty member's release from teaching obligations.

Students who engage in these research projects are either selected by the chairs or managers, or they respond to a job announcement, and they are duly compensated for their contributions. Compensation can be in the form of hourly wages or as part of a capstone project, providing students with valuable hands-on experience and tangible rewards for their efforts.

The Office of Applied Research and Innovation, consisting of 16 dedicated employees, serves as a valuable resource for applied research activities. This office plays a pivotal role in supporting the research chairs and managers by handling administrative and financial matters. Moreover, it actively assists students interested in participating in applied research projects and facilitates connections between business partners and researchers, including assistance with fundraising initiatives.

3.3 Financing

The applied research centres at Saskatchewan Polytechnic receive core funding from the institution. The objective is for the research chairs in each centre to attract enough funding within three years to offset the initial investment made by the institution. The funding for these centres comes from diverse sources, including federal government funding, fee-for-service work, grant funding, and private sector research contracts. The overhead costs are shared between the research centre and the institution.

In the 2021-2022 period, the total external funding for applied research projects amounted to $9,060,012, and the total revenue generated from applied research was $11,113,126. This marked a significant 77% increase compared to the previous year (Saskatchewan Polytechnic, 2022).

The Office of Applied Research and Innovation at Saskatchewan Polytechnic supports business partners involved in applied research projects by assisting them in applying for regional or federal grants. Depending on the circumstances, these grants may cover 50% or more of the total costs. However, some business partners opt to cover all expenses themselves, as the grant application and administration process can be time-consuming. The ability of business partners to cover research project costs varies across different research areas. Notably, CHRIS in the healthcare field relies more on grant funding, as the not-for-profit health system has limited opportunities for providing financial support.

For students participating in applied research, designated scholarships are available. Each eligible student can receive a scholarship of $1,000. These applied research scholarships aim at offering students at Saskatchewan Polytechnic an opportunity to engage in applied research partnerships with industry and community. To apply for

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a scholarship, students are required to submit a research plan and a project summary. Additionally, students may also be hired to work on applied research projects as an extracurricular activity.

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4. Approach to applied research

Applied research at Saskatchewan Polytechnic acts as a vital link between conceptual ideas and practical implementation, with the primary goal of delivering innovative solutions for business partners. The institution's approach to fostering innovation entails a comprehensive process of needs assessment, concept validation, and product testing to enhance their market viability. The applied research centres play a pivotal role in assisting business partners in overcoming challenges and supporting entrepreneurial ventures during their initial stages. The centres are equipped with state-of-the-art tools and technologies, complemented by dedicated researchers and students.

Most applied research initiatives commence with a business partner, who presents a specific challenge that necessitates resolution and demonstrates their commitment to co-funding a research project aimed at addressing this challenge.

A compelling example is Enviro Integration Strategies, a consultancy and software development company specialising in the mining sector. Enviro sought to enhance their software that assesses risks associated with mine waste facilities, empowering decision-makers to make informed choices and plan effectively. Recognising Saskatchewan Polytechnic's expertise, Enviro approached the institution's DICE centre for support in further developing their software. Initially, the company only sought assistance from a student to aid in the development process. However, through a wage subsidy grant programme, funding for a research project was secured enabling Saskatchewan Polytechnic to help Enviro secure additional grants and subsidies to hire more developers and advisors for the project.

The CEO of Enviro Integration Strategies emphasises that engaging in the research project was instrumental in fostering the innovation necessary for the company, ultimately benefiting the mining industry. Without the research project and the funding opportunities provided by the grant programme, the development of the software would have been challenging for Enviro, due to the high costs typically associated with software development and potential complications surrounding intellectual property rights. Saskatchewan Polytechnic operates under the principle that clients who bring ideas or intellectual property for further enhancement retain ownership of the results. Thus, any intellectual property belonging to the client remains their exclusive possession (Saskatchewan Polytechnic, 2023).

Enviro Integration Strategies contributed with the initial idea, co-funding, and willingly collaborated in managing the development process for over two years, working closely with both the students involved in the project and the researchers from DICE. From DICE’s perspective, engaging in the project provided the opportunity for some of their students to benefit from problem-based learning and increase their employability significantly.

As the Enviro case demonstrates, the approach to fostering innovation and applied research involves a close engagement, also financially, with business partners throughout the implementation of a research project. It involves students working on research projects supported by researchers, in this case from DICE, while members of other faculties also may engage in applied research projects.

It should be noted that the approach to applied research differs in the fields of nursing and health sciences. CHRIS conducts research to solve health-related problems for communities or individuals. The focus is more academic, and it involves writing papers and sharing knowledge. One example is a research project on mental health in rural farming communities and the development of a mental health toolbox for farmers and ranchers. The beneficiaries of this research project neither have the same capacity nor the financial resources to engage in the research as other business partners. Instead, fund-raising for research projects plays a crucial role, although CHRIS is also receiving donations from large farms, ranchers, and agricultural companies for their research.

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Figure 5: Through a partnership with Glacier Farm Media, Saskatchewan Polytechnic has access to Discovery Farm – a 610-acre research, demonstration and event site near Langham, Saskatchewan. This allows for real-world testing and field-level experiments in key areas such as water management, soil health, and crop development. (Image: Glacier Farm Media)

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5. Impact of innovation activities

Applied research at Saskatchewan Polytechnic has a significant impact on the Province of Saskatchewan by providing practical solutions, supporting technological advancements, fostering industry collaboration, addressing societal challenges, and offering funding support. These efforts contribute to economic growth, job creation, improved healthcare, and overall development of innovative solutions – not only in Saskatchewan, but also in other parts of Canada.

In terms of technological advancement, Saskatchewan Polytechnic's applied research aims to support the manufacturing sector in adapting to technological advancement and rapidly changing innovations across various industries. Through applied research partnerships, the institution helps businesses access services like prototyping, testing, and certification, which may otherwise be expensive or difficult to find. The IMC at the Regina and Saskatoon campuses provides advanced infrastructure for machining, manufacturing, and additive manufacturing (3D printing). This enables businesses, including start-ups, small- to medium-sized enterprises, and large manufacturers, to access the necessary tools and expertise for innovation and growth. One example of the impact of innovation activities is Saskatoon's LightLeaf Solar, a company specialising in solar panels for mobile applications like boats, trailers, and vehicles. The company sought a more efficient and safer method for assembling their solar panels. The company approached Saskatchewan Polytechnic to explore how the institution could assist with their manufacturing challenge. IMC collaborated to find solutions and with the help of a grant, a team at Saskatchewan Polytechnic utilised 3D printing and mechatronics to automate the solar cell process and improve the trimming of the final product. The collaboration resulted in significant advancements in LightLeaf's manufacturing processes and increased their competitiveness (Industry West Magazine, 2023).

Figure 6: 3D printing in the Innovative Manufacturing Centre (IMC) (Image: Saskatchewan Polytechnic)

Another example of a concrete impact of the innovation activities is the International Minerals Innovation Institute (IMII) and their collaboration with DICE to improve existing technology for enhancing safety in underground mining. While GPS technology is effective on the surface, it does not work underground, and the mining industry was after a better solution for locating people and equipment. IMII, DICE and industry partners BHP and Nutrien joined forces to address this issue. The project received a total investment of $314,000 from

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IMII, BHP, Nutrien, and an additional $324,000 from NSERC's Applied Research and Development programme. Researchers from DICE with support from students developed a prototype for the first phase of the project. The prototype will, subsequently, be tested in collaboration with mining partners on separate projects, tailoring the solution to specific mining environments. The project benefits IMII by advancing the industry and providing training on the technology's usage (Industry West Magazine, 2023).

However, applied research initiatives at Saskatchewan Polytechnic go beyond industry partnerships. The Saskatchewan Centre for Patient-Oriented Research (SCPOR) focuses on engaging patients as partners in research to address pressing healthcare issues. SCPOR connects patients, caregivers, and researchers to incorporate diverse perspectives, including those of indigenous communities, recent immigrants, and refugees. The research aims at improving care quality, reduce disparities, and align with provincial health priorities.

Besides the impact on economic growth and job creation, the applied research programme also has a significant impact on Saskatchewan Polytechnic as an institution. In 2021-2022, applied research projects were undertaken with 57 companies and external organisations involving 159 faculty members and researchers. In addition, 347 students from Saskatchewan Polytechnic were paid participants in applied research (Saskatchewan Polytechnic, 2022).

For the students, the involvement in applied research projects promotes skills and competences that are difficult to obtain through theoretical learning. These skills and competences include critical thinking, problem-solving and an innovative mindset. The students are also trained in interacting with business partners and, according to the interviewed researchers, the experiences gained by the students are highly beneficial for their future employment prospects, as many students are hired by the companies they collaborate with.

The applied research programmes not only contribute to the development of research capabilities, but they also facilitate the growth of faculty members involved in the projects. Through collaborations with business partners, researchers stay connected with the evolving needs and advancement in the industry. They can incorporate practical examples and hands-on experiences gained from the collaborations into their teaching, enhancing the relevance and quality of their instruction. Additionally, the availability of external funding and grants enables Saskatchewan Polytechnic to invest in new equipment more frequently than many other institutions. This provides students and faculty members with access to state-of-the-art facilities.

Figure 7: Collaborative project using ground penetrating radar at the site of the Marieval Indian Residential School, on the Cowessess First Nation. (Image: Saskatchewan Polytechnic)

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6. Systemic enablers and obstacles

This section takes a closer look at some of the enablers that contribute to the positive developments within applied research at Saskatchewan Polytechnic. At the same time, the section examines some of the obstacles that hinder further progress.

All interviewed researchers unanimously state that the positive development of applied research at Saskatchewan Polytechnic starts at the top. It has been a strategic management decision to give priority to applied research, and the institution's president is personally very committed to pushing this agenda. This means that resources are allocated to the area, and it is viewed positively if faculty members want to be partly relieved of their teaching obligations to dedicate themselves to research.

The strategic focus has also resulted in the establishment of a support unit, the Office of Applied Research and Innovation, that helps remove many practical obstacles for researchers and external partners participating in research projects. The support unit has grown from 2 to 16 employees in just 7-8 years, reflecting the significant growth applied research has experienced at Saskatchewan Polytechnic.

Another important driver of applied research is to have employees whose main task is to concentrate on applied research. According to interviewees, the establishment of centres with a permanent chair for each centre has made it possible to maintain focus on research activities and to reach out to potential partners.

A third important factor is that the opportunities to engage in applied research projects are known and recognised by external collaborators. This requires the establishment of networks between Saskatchewan Polytechnic and business partners, and investment in promotional materials with compelling cases that can be disseminated. For business partners to be interested in collaborating, it is essential that the barrier to entry is low in terms of administrative burdens. Furthermore, that access to technological equipment is attractive, and finally, that business partners do not risk losing intellectual property rights. Therefore, it has been a central decision at Saskatchewan Polytechnic to allow business partners to retain the rights to all intellectual property developed within a given project.

Funding opportunities are naturally crucial. Both regionally and nationally, there are several funding options that enable collaboration, thus reducing the financial burden on business partners. Funding opportunities are also essential for Saskatchewan Polytechnic to establish applied research projects and for investment in facilities.

While funding is an enabler, it can also be a barrier. Business partners describe the funding programmes as burdensome to apply for and administer, despite support from the Office of Applied Research and Innovation. There may also be a time delay between funding needs for business partners and the funding payout.

Another barrier mentioned by several researchers is that there has not been a tradition among faculty members to participate in applied research projects, and there may not be anything in the system that makes it attractive to be relieved of teaching to become part of a research project. It is, therefore, driven by individual motivation.

Finally, competition from universities is highlighted as a barrier in the healthcare field, where applied research is more academic. Many researchers in nursing and health sciences eventually move to universities due to better wage structures.

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7. Conclusion

Saskatchewan Polytechnic offers a diverse range of applied research programmes within fields like agriculture, artificial intelligence, biotechnology, and biomechanics. These programmes are designed to tackle real-world problems and provide tangible solutions.

At Saskatchewan Polytechnic, applied research is a strategic priority receiving dedicated support from the Office of Applied Research and Innovation. This office serves as a facilitator promoting industry engagement, fostering collaboration with business partners and raising funding. The applied research programmes are structured within specialised centres, which bring together experts from different disciplines.

To facilitate applied research activities, Saskatchewan Polytechnic provides cutting-edge facilities and equipment. Industrial partners gain access to state-of-the-art laboratories and advanced tools across the institution's campuses. The human resources dedicated to applied research include experienced researchers, faculty members, and students, who actively contribute to ongoing projects. Furthermore, the institution offers financial support through core funding, external grants, student scholarships, and assistance with grant applications.

Saskatchewan Polytechnic takes an innovative approach to encourage the translation of conceptual ideas into practical implementations. By closely collaborating with business partners, the institution addresses specific challenges, and supports entrepreneurial ventures. This approach involves conducting needs assessments, validating concepts, and rigorously testing products to deliver innovative solutions.

The positive development of applied research at Saskatchewan Polytechnic can be attributed to strategic management decisions, supported by the institution's president, who actively advocates for applied research and allocates the necessary resources. The establishment of the Office of Applied Research and Innovation has played an important role in overcoming practical challenges and has contributed to significant growth in applied research. The presence of dedicated employees and research-focused centres has also been an asset.

The prioritisation of low administrative burdens, access to technology, and the retention of intellectual property rights through the creation of networks and promotion materials has helped attract external collaborators and business partners.

Funding is essential for the initiation of collaboration. However, it can be a burdensome process and difficult to manage. The lack of tradition for faculty members to engage in applied research projects and competition from universities pose barriers as well as delays in obtaining funding.

The impact of innovation activities at Saskatchewan Polytechnic extends beyond the institution itself. Applied research initiatives contribute positively to the province by driving economic growth, creating job opportunities, improving healthcare, and fostering the development of innovative solutions. These research efforts also support the regional economic strongholds and provide valuable practical experiences for students, enhancing their employability.

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E. Waag FutureLab

1. Introduction

Waag Futurelab (Waag) is a pioneering Dutch NGO based in Amsterdam that has been at the forefront of digital innovation and civic engagement for three decades. It was established in 1994 by a group of early internet adopters, who were self-taught coders and builders of some of the first websites. They received support from the Amsterdam municipality, which saw the potential of the internet beyond just a passing trend. From building one of the first online internet communities in the Netherlands known as the Digital City, Waag has grown into a multifaceted organisation involved in a wide range of initiatives.

The organisation is neither an academic nor an educational institution offering programmes, but rather a collaborative and innovative entity. It focuses on engaging the public in research through a variety of activities and concepts with the aim of engaging citizens in questions of how technology can address societal challenges. It has its own lab facilities and provides educational institutions and others with advice on how to establish their own lab facilities and engage communities in ‘critical making’.[9] Waag assists communities in creating prototypes, finding alternative solutions, and working together.

Figure 1: ‘de Waag’ building in Amsterdam, home to the organisation Waag. (Image: Waag)

Waag was one of the early adopters of the Fablab concept in Europe, meaning small-scale workshops that promote innovation by providing access for individuals and communities to tools for digital fabrication. Within Waag, there are a range of different laboratories or workshops offering different resources and technologies for experimentation and creation, including the FabLab, TextileLab, Wetlab, Design Lab, and Maker Education Lab.

[9] Critical making is a practice that unites critical thinking and hands-on experiments to encourage learning by doing. Drawing from constructionist approaches to project-based learning, critical making explores the relationships between technologies, art, design, and social issues by making things (Butts, 2022).

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Waag promotes participatory design, critical making, and citizen science to encourage the public's active involvement in shaping the digital future. Its mission is to increase people's agency and to ensure that the emerging digital society benefits everyone. Waag uses the term ‘public research’ to denote its approach to applied research. They lead and participate in projects that aim to engage communities in co-creating knowledge and solutions to local or societal challenges. The approach is grounded in the principle that all individuals possess valuable knowledge, skills, or experiences that can significantly enrich collective understanding. This perspective helps Waag ensure that research is not limited to academia or corporations, but rather co-created with the broader public. Waag public research also plays a crucial role in the development of the key enabling methodologies as outlined in the Dutch Knowledge and Innovation Agenda of CLICKNL.[10]

Waag’s research is organised into four groups: Code, Life, Make, and Learn – with each being overseen by a head of programme:

- **Code** focuses on demystifying engineering.
- **Life** promotes empowering people and nature.
- **Make** explores making practices and materials.
- **Learn** studies learning skills and attitudes.

Each of the four groups has one or more of Waag’s labs attached. However, all groups and labs at Waag work together to combine insights for a shared approach to research. The aim is to impact society positively, with research impacts regularly updated on Waag's website (www.waag.org). Guided by the principles of participatory action and driven by a hacker mentality, they engage in public research focusing on areas such as health, education, culture, sustainability, and data governance.

1.1 The Learn division at Waag

In this case study, we focus on the educational activities and philosophy at Waag’s Learn division. Led by Pam de Sterke, the team at Learn has formerly worked extensively in heritage and heritage preservation, seeking ways to make heritage more inclusive. However, the division is now shifting its focus towards maker education, a concept that has been evolving within the organisation.

Maker education is a teaching philosophy that emphasises hands-on learning, collaboration, design thinking, and digital fabrication. It uses tools such as 3D printers, laser cutters, CNC machines, and even traditional workshops to allow students to design and create physical objects in response to challenges and issues faced by local and wider communities. Learn's key slogan is ‘learning by making,’ and this philosophy guides their approach to education.

Concepts such as critical making, technological citizenship, and open schooling reflect how they envision educational institutions to instil a maker mindset in citizens that fosters creativity, resilience, collaboration, and self-efficacy. All skills that Waag identifies as essential for the 21st century – as further discussed in chapter 4 of this case study.

[10] CLICKNL is a publicly financed Dutch initiative aimed at fostering innovation and growth within the creative industry. It functions as a networking platform, bringing together researchers, creatives, and businesses to collaborate on research and innovation projects and to exchange knowledge and ideas. More on the knowledge and innovation agenda here: https://www.clicknl.nl/en/knowledge-and-innovation-agenda/

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Learn investigates how we can use and rethink educational practices to equip students with skills to critically engage with technology, make social issues visible, and discover how digital making skills can empower students to engage with new ideas for how we might move towards a more inclusive, equitable, and sustainable society.

The Learn division at Waag does not itself offer educational programmes. They research approaches to develop the technological citizenship and critical making skills of young people. Further, they work with educational partners, such as high schools and public libraries, to develop and implement new maker education programmes, courses, and workshops – or help integrate maker education into existing courses and educational programmes.

In this case study, we focus on three of the Learn division's current projects:

1. **Make it Open:** This project is about open schooling and seeks to promote partnerships between schools and their neighbourhood by letting students engage critically and creatively with local challenges and issues in need of new ideas and solutions. More than 800 students (aged 13-16) from high schools are engaged in this project.
2. **Amsterdam Maakplaats 021:** This project is a maker education programme implemented in ten public libraries in Amsterdam placed in low-income neighbourhoods with the goal to train young people in digital making skills. Waag trains the employees in maker education and digital fabrication.
3. **Technological Citizenship:** Together with partners and youngsters, Waag investigates through workshops how creative making processes can develop the citizenship skills of young people in a digital society.

These three projects form the basis of this case study. They all build on the philosophy of maker education with its core concepts mentioned above. The following sections describe the management and organisation of activities, the resources needed, the underlying teaching and innovation philosophy, the impact of the maker education approach, and, finally, the main obstacles to the successful implementation of maker education in new or existing educational programmes.

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2. Management and organisation

Waag is financed by the Dutch Ministry of Education, Culture and Science, and the City of Amsterdam. In addition, Waag participates in projects funded by public institutions and organisations, such as the European Commission, CLICKNL, and Grant for the Web. It employs 68 people as of June 2023 divided between the four programmes: Code, Life, Make, and Learn. Each group is led by a head of programme, and each group has one or more labs with an associated lab lead. Each programme is involved in multiple ongoing projects that engage external partners and communities.

The Learn programme has two labs. The Future Heritage Lab and the Maker Education Lab. Besides the Head of Programme, Pam de Sterke, the Learn division employs 12 people, some of whom are interns. The Future Heritage Lab engages in questions about which cultural traditions, buildings, or works of art constitute heritage, and the role that heritage plays in contemporary debates about identity, ecology, and social cohesion. The Maker Education Lab focuses on contemporary and new forms of learning, particularly by promoting a maker mindset and critical engagement with new technologies and by working with new technologies hands-on.

Each lab has several projects running simultaneously, and they can be small or large. Make it Open is a large project that involves most of the Learn team. Currently, The Maker Education Lab has 10 ongoing projects. In this case study, we focus on three of their prominent projects: Make it Open, Amsterdam Maakplaats 021, and Technological Citizenship. We use these projects to detail and discuss how the maker education approach is practiced, the potential impact of this approach, the resources needed, and the potential obstacles involved in succeeding. Below, we will start by describing the activities and how they are organised in each of the three projects.

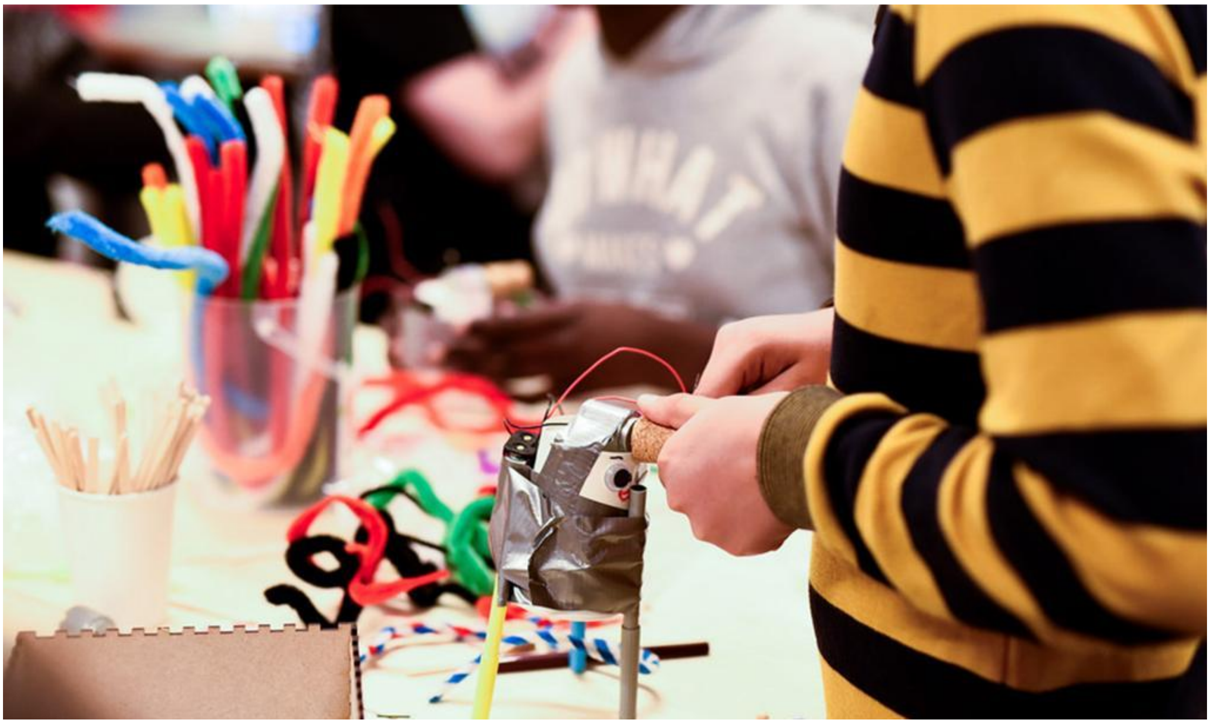

Figure 2: Young learners involved in creative making. (Image: Waag)

2.1 Make it Open

Make it Open is a project aimed at constructing a robust, sustainable framework for open schooling across Europe. The project is financed by the Horizon Europe programme. The central idea is to reorient the educational landscape in order for schools to open themselves up to the wider community and engage students, through

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teaching, in the challenges and issues occurring in the neighbourhood. Its aim is to create a dynamic and interactive environment where the exchange of knowledge can effectively serve both students and neighbourhood alike.

A key component of Make it Open is the Open Schooling Navigator, an online platform conceived in collaboration with Ir. Lely Lyceum and Montessori school De Regenboog in Amsterdam Zuid-Oost, as well as pilot schools in Warsaw, London, and Jerusalem. The Navigator houses a repository of learning materials and scenarios produced through the Make it Open pilot projects and is designed as a tool for educators and schools to kick-start and maintain their own open schooling initiatives.

Additionally, Make it Open features a large-scale collaborative project known as ’Technasia,’ which involves over 800 students, aged 13 to 16, from high schools in North Holland. A key partner in this endeavour is the Technetium Foundation, an organisation specialising in preparing students for technical studies via project-oriented learning. Schools associated with Technetium are equipped with maker spaces[11] and follow a design process that encourages problem-solving, pitching, prototyping, and teamwork in small groups.

The students collaborate on a design assignment titled 'The Circular Neighbourhood', a project that encourages students to highlight and showcase local makers in their neighbourhood, promoting a ‘maker mentality’ among young learners. This process involves students identifying residual material flows in their community and designing solutions aimed at creating a circular economy. The students' designs are ultimately used as roadmaps for similar future projects.

The open schooling approach, championed by Waag, advocates for schools to become community hubs of learning, instead of limiting their function to serving students of specific age groups. This outlook aims at engaging a wide range of stakeholders - parents, community members, and others - in the educational process. It is hypothesised that this method, when aligned with community interests and needs, can potentially enhance students' performance in STEM subjects.

Waag plays a crucial role as a facilitator of professional development for educators, offering bespoke training designed to equip teachers with the necessary skills to implement the novel concept of open schooling effectively. Waag's role, in terms of training teachers, is multi-faceted combining the provision of technical skills, pedagogical strategies, and ongoing collaborative support. Waag acts as a resource, mentor, and partner to educators as they navigate the landscape of open schooling.

2.2 Amsterdam Maakplaats 021

The Amsterdam Maakplaats 021 project involves implementing maker spaces (maakplaats) in ten public libraries in Amsterdam and developing maker education programmes to engage children in the neighbourhoods. The project focuses on low-income areas of the city to bring maker education and opportunities to all. The project is a collaboration between several entities - the public libraries of Amsterdam (OBA), Pakhuis de Zwijger, a community of city makers, students from the Amsterdam University of Applied Sciences, and Waag.

The team consists of 13 maker space coaches, who cater to after-school programmes, primarily for children and young adults living in these neighbourhoods. The project team also includes an educator and a coordinator,

[11] A maker space, sometimes referred to as a ‘hacker space’ or ‘fablab’, is a collaborative workspace inside a school, library or other public facility, for making, learning, exploring, and sharing. These spaces can include a variety of maker equipment including 3D printers, laser cutters, CNC (Computer Numeric Control) machines, soldering irons, and even sewing machines.

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responsible for the logistical aspects of the programmes. This initiative, which commenced about five years ago, has been financially backed by the city council.

The libraries, venturing into the new territory of housing maker spaces, sought Waag's expertise in setting up such spaces, understanding new technologies, designing suitable programmes for children, and most importantly, training their staff to change from traditional teaching roles to becoming coaches in the maker education environment.

One fundamental aspect of the project is its focus on the neighbourhoods where the participants live. Rather than just focusing on individual skills and knowledge, the programmes often prompt participants to explore their neighbourhoods, study the people, animals, and surroundings, and reflect on the challenges and possibilities that exist within these spaces. Students are encouraged to consider how they would transform their environment given the opportunity, effectively linking their maker education with civic awareness and responsibility.

To optimise the use of the maker space and reinforce these partnerships, the Maakplaats 021 project opens its doors to partner organisations when the space is not in use for its own programmes. Not only does this maximise the utility of the maker space, but it also fosters a sense of community ownership, enhancing the project's integration into the neighbourhood.

2.3 Technological Citizenship

In the Technological Citizenship project, the critical making process serves as a vehicle for students aged 15 to 18 to delve into issues around technological citizenship in a tangible and open-minded way. Waag organises workshops for the students through which they are encouraged to understand and question the technology they use, focusing on areas such as data gathering, deceptive media, and artificial intelligence. Alongside students, the project research ethical decisions and implications tied to these themes encourage participants to not only use technology, but to understand and question it.

The methodology of the workshops is centred around the principles of critical making, which seeks to inspire intrinsic motivation in participants by triggering emotional responses to social issues. This involves examining an object or an idea and considering what type of users or individuals it excludes – and how this can be used for discussion and application. The intention is to provoke thoughts about how the showcased work makes them feel and how it relates to their personal experiences.

Specific examples of critical making are used to provoke discussions on relevant topics. For instance, a project titled 'The Feminine Urge' by Max Oosterholt, which explores the impact of TikTok on body image and the potential for harmful consequences, is used as a starting point for dialogue. The reactions to this content aid in gauging the attitudes of the students and provide a base for further conversation and exploration.

The project follows a collaborative model joining forces with students and partner organisations, including the Rathenau Institute, Designathon Works, NewTechKids, and the Christelijke Scholengemeenschap Buitenveldert (a school at the border of Amsterdam and Amstelveen).

Waag aims at extending the influence of the project beyond the immediate participants and strives to translate the knowledge and insights gained from the project into principles for the creative industry to promote more socially responsible innovations there. Thus, Waag's role in the project spans from implementation of the project's teaching methods to influencing industry practice.

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3. Resources

Implementing open schooling and maker education initiatives as well as instilling a maker mindset in students requires several key resources. The resources below are the ones identified by those interviewed for this case study.

Dedicated personnel with specialised skills: Teachers play a pivotal role in these initiatives. They should not only be knowledgeable in their respective fields, but also enthusiastic, open to learning, and eager to engage with new topics. Such attributes make teachers more effective and inspiring to students. Their enthusiasm also motivates students and makes the learning process more enjoyable. However, not all teachers can be expected to possess maker skills, which is why some of them should be upskilled or employed with these specific abilities. These teachers would be instrumental in running the programmes or assisting teachers without these skills. There may also be a need for a collaboration between teachers and external makers to provide the requisite skills and knowledge.

Figure 3: Teacher with students at one of Waag's partner schools. (Image: Waag)

Equipment and maintenance: Access to well-equipped maker spaces is crucial for successful implementation. Schools need equipment and machines to facilitate learning. However, it is also necessary that staff members know how to maintain and operate these machines. Often, expensive equipment goes unused simply because there is no one who knows how to operate or maintain it. Hence, there is also a need for staff members, likely teachers, to be upskilled so they can maintain the equipment. Specifically, there must be more than a single teacher with these skills, so that the sustainability of maker education initiatives does not rely on a single person.

Time for experimentation: Teachers need to have some time set aside for their own experimentation. This enables them to familiarise themselves with the equipment, discover what they can do in the maker space, and cultivate their own excitement about the possibilities. This enthusiasm is often contagious and can help drive student engagement.

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Adapting the curriculum: The existing school curriculum may need to be adapted or supplemented to include the principles and practices of maker education. This could mean incorporating more hands-on activities, creating opportunities for critical thinking, and designing experiences that allow students to engage with technology in meaningful ways. The curriculum should be flexible enough to allow the integration of these new concepts and practices.

Professional development opportunities: Offering courses or training for teachers can help cultivate their excitement about the possibilities of the maker space and then transfer that excitement to their students. This might involve training on specific maker tools or more general instruction on pedagogical approaches to maker education.

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4. Approach to fostering innovation

Maker education, also known as maker-centred learning, is an innovative approach to teaching and learning that encourages students to learning by doing. It is heavily influenced by the ethos of the maker movement, which values creativity, ingenuity, and hands-on problem-solving (Clapp, Ross, Ryan, & Tishman, 2016).

At its core, maker education is about providing students with opportunities to engage in creative and critical thinking through the process of designing, constructing, and iterating on their own projects. It leverages a range of tools and technologies - from traditional craft materials to high-tech digital fabrication tools like 3D printers and laser cutters.

Key principles of the maker education approach are:

- **Student-centered learning:** Maker education emphasises self-directed, experiential learning where students are at the centre of the learning process. Students are given the autonomy to choose projects that align with their interests, which can lead to greater engagement and intrinsic motivation.
- **Hands-on exploration:** Instead of learning by rote or traditional lectures, students learn by doing. They build, create, and tinker with physical and digital tools to gain a deeper understanding of concepts.
- **Iterative design:** Students learn to embrace failure as a natural part of the learning process. They are encouraged to experiment, iterate, and learn from their mistakes in a process similar to the engineering design process.
- **Developing a maker mindset:** Maker education is not just about the skills and knowledge gained, but also about developing a mindset that values curiosity, resilience, creativity, and problem-solving. Maker education encourages students to think critically about the world around them and use their skills to solve real-world problems.

Waag Learn, however, expresses a degree of scepticism about the 'solution focus' or the idea that every problem can be solved. Instead, they suggest that a more useful skill for the future would be dealing with uncertainty and preparedness for various scenarios, a concept they refer to as 'futures literacy.'

They advocate for playfulness and creativity in learning, indicating that the process and the skills gained are more important than the tangible end products of student projects. They believe that this approach is applicable to learners of all ages, not just children.

Open schooling and maker education, when combined, create a certain educational paradigm. The open schooling approach extends beyond traditional classroom learning to create a more integrated, community-oriented and experiential learning environment. Open schooling encourages collaboration not just among students, but also between schools, communities, and other stakeholders, fostering a shared responsibility for education. In essence, the open schooling approach seeks to create a more holistic, inclusive, and engaging learning environment that prepares students for lifelong learning and active participation in society. It is about transforming schools into open learning environments that effectively connect students, teachers, families, and the wider community.

Open Schooling and maker education potentially complement each other in the following ways:

- **Enhanced engagement:** Both open schooling and maker education aim to enhance student engagement. Open schooling encourages active learning by involving learners in real-world problems and community issues. Maker education, on the other hand, fosters hands-on learning through making, crafting, and tinkering. Combined, these two approaches can result in a highly engaging and stimulating educational experience.

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- **Real-world learning:** Open schooling is often characterised by the integration of community resources and real-world problems into the curriculum. This fits well with the maker education's ethos of encouraging learners to use their creativity and problem-solving skills to create tangible solutions to real-world problems.
- **Learning beyond the classroom:** Both approaches emphasise learning beyond the traditional classroom. Open schooling extends learning into the community and involves learners in community service, internships, and other out-of-school experiences. Maker education can happen anywhere – in maker spaces, at home, in community centres, etc. – making learning a continuous, everywhere experience.

Figure 4: Students participating in the project 'Circular Neighbourhood' (Image: Waag)

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5. Impact

In theory, open schooling and maker education approaches can have a transformative impact on students. The goal is to promote active learning, stimulate creativity, enhance critical thinking, and encourage students to take ownership of their education. Below are the kind of learning goals that Waag hopes to promote by engaging students, schools and communities in maker education:

- **Active learning:** Students engage more deeply with the material when they are actively involved in the learning process, whether they are designing, creating, or solving a problem. They are not just passively absorbing information, but actively applying it.
- **Creativity and innovation:** Maker education nurtures creativity and innovation as students are encouraged to develop their ideas into tangible projects. They learn to think outside the box and create unique solutions to problems.
- **Critical thinking:** Both approaches foster critical thinking skills as students learn to analyse situations, consider multiple perspectives, and make informed decisions.
- **Collaboration and communication skills:** Both approaches often involve collaborative projects where students work in teams, enhancing their communication and collaboration skills.
- **Autonomy and ownership:** Students have more autonomy in their learning and take more ownership of their educational journey. This can boost their self-confidence and prepare them for lifelong learning.

Despite these potential benefits, it is important to note that it can be challenging to empirically measure the impact of such educational approaches. In the case of Waag, they currently do not have evaluations or effect studies documenting the effect of their programmes. This may be due to the complexity and diversity of the learning experiences in open schooling and maker education initiatives, which do not lend themselves easily to traditional evaluation metrics.

The focus of Waag's projects seems to be process orientation, sparking curiosity, and engaging students in meaningful projects. They seem to value the hands-on experience and the lessons learnt during the process, rather than the actual product or output.

It is clear that these projects are appreciated by teachers and students alike, and that they offer valuable learning experiences. However, without formal evaluation or effect studies, it can be challenging to quantify their impact and to compare their effectiveness with other educational approaches. The anecdotal evidence provided suggests a positive impact, but more structured studies would be needed to confirm this.

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6. Systemic obstacles

The interviewees for this case study were asked to reflect on the major obstacles that could potentially create significant barriers to implementing open schooling and maker education initiatives in schools. They emphasised issues relating to scalability, time and resources, and the recognition of maker education skills as equally important to other skills taught in school.

The interviewees highlight that innovation tends to be easier with smaller groups. This creates a challenge when trying to scale these innovative practices to larger groups of students, potentially limiting the overall impact of such initiatives.

Secondly, it is emphasised that teachers need to have time and resources to arrange and plan these courses and programmes. This can be particularly challenging in contexts where there is a shortage of teachers, or where resources are stretched thin. Arranging open schooling and maker education is potentially time-consuming, so it must be something that the school decides to prioritise. For many schools, this could be a challenge within their normal budget.

Finally, they point to a problem related to the perception of maker education skills. These skills are often not deemed to be as important as other skills traditionally addressed by formal education, such as maths and language skills. This can hinder the integration of maker education into school curricula, particularly in periods with limited resources. For example, the interviewees reported that in certain situations, e.g., when students fell behind in basic skills like reading and writing due to the coronavirus pandemic, extra resources were directed towards the basic skills, leaving little for initiatives like maker education.

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7. Conclusion

In conclusion, the case study of Waag Futurelab's LEARN division provides valuable insights into maker education and its impact on students, schools, and communities. The LEARN division focuses on developing critical making skills and technological citizenship among young people, promoting a maker mindset that fosters creativity, collaboration, and self-efficacy.

Waag's learning strategy emphasises hands-on learning, design thinking, and digital fabrication. By integrating concepts such as critical making, open schooling, and technological citizenship, Waag envisions educational institutions that instil a maker mindset in citizens to address societal challenges and contribute to a more inclusive, equitable, and sustainable society.

The LEARN division is involved in various projects, including Make It Open, Amsterdam Maakplaats 021, and Technological Citizenship. These projects showcase the practical application of the maker education approach. Make It Open focuses on open schooling, engaging students in local challenges and promoting collaboration between schools and communities. Amsterdam Maakplaats 021 brings maker education programmes to low-income neighbourhoods through public libraries, fostering a sense of community ownership and civic awareness. Technological Citizenship empowers students to critically engage with technology and explore ethical implications through workshops and collaborative projects.

Waag's impact on education is its ability to enhance student engagement, nurture creativity and innovation, foster critical thinking, and promote collaboration and communication skills. The open schooling and maker education approaches provide opportunities for active learning, autonomy, and ownership, preparing students for lifelong learning and active participation in society.

However, it is important to note that the impact of these initiatives has not been extensively evaluated. Waag currently lacks formal evaluation or effect studies to quantify the outcomes of their programmes. While anecdotal evidence suggests positive outcomes, further research is needed to provide a comprehensive understanding of the effectiveness of open schooling and maker education in achieving educational goals.

The implementation of open schooling and maker education initiatives faces systemic obstacles. Scaling these innovative practices to larger groups of students can be challenging, requiring additional time, resources, and support for teachers. Further, the limited recognition of the importance of maker education skills can hinder their integration into school curricula, especially when faced with resource constraints.

Despite these challenges, Waag Futurelab's LEARN division serves as a pioneering force in the field of maker education. Through their collaborative projects, they continue to inspire students, educators, and communities to embrace a maker mindset, fostering a culture of innovation, curiosity, and resilience.

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Main findings and lessons learnt

Image: ‘ThisisEngineering REA’ on Unsplash)

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III. Main findings and lessons learnt

This chapter contains the key findings and lessons learnt from a cross-case analysis of the five conducted case studies. It presents common patterns and themes, while also highlighting significant differences between the cases, with regard to their approach of organising and conducting applied research to foster innovation.

Since this best practice study is meant to serve as inspiration to further activities in the Challenger project, the following sections focus on highlighting those findings that may help and inform the development of a new framework for the sustainable integration of applied research into VET. These include, for instance, lessons learnt on the resources required for integrating and conducting applied research, as well as on its use as a teaching and learning strategy.

To present an accessible and useful overview of the main findings, this chapter is structured according to the five analytical dimensions that were used as a framework for each conducted case study (with one section dedicated to each dimension). It can be read independently from the case studies.

III.I Management and organisation

Findings from the case studies suggest that **a successful integration of applied research into VET requires the establishment of dedicated organisational units** by VET providers. All of the educational institutions examined for this best practice study have anchored applied research in their organisational structure by creating centres, departments, or offices that are responsible for co-ordinating and supporting applied research activities. It is also **a common trait among these institutions that they have established applied research centres or innovation centres focussing on a specific research area**, for example in relation to an industry sector or a technological field.

At the Copenhagen School of Design and Technology (KEA, Denmark), for instance, the department named KEA Research, Career & Relations has a central function for the planning and implementation of applied research activities. Its research assistants support teachers in charge of applied research projects by doing some of the necessary administrative work, while its research consultants contribute with academic and technical expertise. At KEA, applied research is conducted in four areas, namely construction, digital, design, and technology (e.g., robotics and other state-of-the-art technology). Accordingly, there is one dedicated department for each applied research area (i.e., KEA Build, KEA Digital, KEA Design, and KEA Tech) and research consultants with the KEA Research, Career & Relations department are associated with and support these centres according to their expertise.

In a similar manner, applied research centres or innovation centres at the Singapore Institute of Technology (Singapore), the Holmesglen Institute (Australia), and Saskatchewan Polytechnic (Canada) play a key role in organising and conducting applied research. In general, t**he dedicated centres offer support through a wide range of activities.** These include:

- identifying project opportunities,
- establishing and maintaining relevant partnerships with industry and other stakeholders,
- securing necessary facilities, equipment, and funding,
- helping with research design and methodologies,
- and engaging students in applied research projects.

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It must be added that innovation activities at the Waag Futurelab (Netherlands) are organised somewhat differently. This has partly to do with the nature of the organisation. As an NGO, Waag Futurelabs aims to engage the public in creative thinking, making, and innovation through a variety of activities and concepts. This is reflected in the NGO's four distinct programmes (i.e., Code, Life, Make, and Learn), which cover a range of topics – from demystifying engineering to empowering people and nature. In contrast to the other four case organisations, Waag Futurelab's activities focus more on promoting innovative and hands-on approaches to learning and research, rather than the production of tangible research outcomes that represent solutions to a given problem. However, this is quite understandable when considering that it is among Waag Futurelab's objectives to provide the public with access to maker lab facilities and to offer advice to educational institutions and others on how to establish their own lab facilities and engage in 'critical making'.

Another general finding regarding the management and organisation of applied research is linked to **the importance of developing and implementing applied research strategies**. Most case organisations have formalised and enhanced their applied research activities as part of a strategic decision, for instance, to increase collaborations with industry and to promote critical thinking and design skills among students.

The Singapore Institute of Technology, for example, seeks to be a research and innovation hub that is working closely with a diversity of industry partners. It has taken strategic decisions to establish a range of applied research centres and innovation centres – including the Design Factory closely examined in case study B – to enhance the innovation capacity of industry partners as well as SIT students.

Similarly, the Holmesglen Institute has chosen to work strategically with the integration and promotion of applied research, seeking to further establish applied research projects, innovation and problem-based learning as part of its culture. Furthermore, Saskatchewan Polytechnic describes in its institutional mandate that it engages in applied research with the help of faculty expertise to support innovation by employers and provide students with critical thinking skills.

Among the educational institutions included in this case study, the Copenhagen School of Design and Technology most notably did not have a specific strategy for applied research. However, its applied research activities are arguably in line with the institution's general strategic focus of educating and upskilling (future) employees with practical skills and theoretical insights within design, technology and business, as well as the ability to think and design sustainable solutions.

III.II Resources

Findings from the conducted case studies underline that **a successful integration of applied research into VET will require human resources that are both willing and capable to engage in applied research**. The examined case organisations use different approaches to ensure that they have teachers, principal investigators, or others capable of conducting applied research, while also ensuring that these are supported by research consultants and assistants.

At Saskatchewan Polytechnic, dedicated research chairs have been appointed to each lead one of the institution's six applied research areas. The work together with research managers and associates in a core research team within each area that is responsible for coordinating with business partners and providing supervision to students participating in applied research projects. The Office of Applied Research and Innovation at Saskatchewan Polytechnic supports these specialised teams, for example by handling administrative and financial matters.

Likewise, the Holmesglen Centre for Applied Research and Innovation can be described as a support centre to the different faculties at the institution that are responsible for running applied research projects. As part of its

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activities, the centre offers capacity building for Holmesglen faculty staff and offers workshops or guidance on project management and the effective dissemination of applied research results.

The Design Factory – as one of several innovation centres at the Singapore Institute of Technology (SIT) – also engages in upskilling activities aimed at faculty staff. These services in support of professional development are important for the Design Factory's ability to provide its services. This is particularly due to the fact that there are only four members in the core team of the innovation centre. To be able to take on larger consultancy projects, the Design Factory engages SIT academic staff – who have either previous experience with design thinking or have received relevant training from the innovation centre – as principal investigators and additional manpower. Furthermore, the Design Factory is able to support the planning and implementation of two design modules (one theoretical, the other practical) that are mandatory for all SIT undergraduate students by relying on an actively established and maintained network of 30 professionals with design expertise.

Another approach to securing specialised staff is taken by the Copenhagen School of Design and Technology, which requires teachers to have completed a previous applied research project to qualify for tenure. Interestingly, the institution's applied research centre also matches each applied research project with one of the institution's librarians for scholarly support. Additionally, the Copenhagen School of Design and Technology ensures that all of its research consultants (see section III.I) hold a PhD and have strong research experience.

On this background, it can be summarised that **investments into human resources must be made to succeed with the integration of applied research into VET.** To attract highly-educated research consultants, for example, institutions will need to be able to pay relatively high wages. And where teachers are meant to conduct applied research activities, they will likely require adequate upskilling – as described in several of the case studies presented in this report. Just as upskilling initiatives need to be financed, it may also become necessary to invest in additional teaching staff to replace teachers that can teach less hours due to their participation in applied research projects.

Next to human resources, **conducting applied research also requires appropriate facilities and equipment**. What precisely is needed depends on the research areas in focus, as well as the problems that are meant to be addressed by applied research activities. The organisations examined for this study all feature or have **access to laboratories, workshops or maker spaces with advanced tools and machinery, which are typically costly to establish**. It can be added though, that innovation in some research areas is also possible with relatively basic tools, such as computers and software applications or cardboard and glue (see case study B, section 4.1).

A prominent example of a well-equipped institution is Saskatchewan Polytechnic, which across its four campuses has facilities that include state-of-the-art laboratories and advanced equipment, including 3D printers, tools for use in the field of molecular biology, as well as robots and collaborative robots. Although not focusing on industrial-grade facilities and equipment, the Waag Futurelab has established several laboratories and workshops offering a range of resources and technologies for experimentation and creation (e.g., TextileLab, Wetlab, Design Lab, and Maker Education Lab).

The Design Factory at the Singapore Institute of Technology does not have its own laboratories or workshops but can make use of a number of laboratories and a maker space belonging to other innovation centres and applied research centres at SIT. This way, the Design Factory can give undergraduate students partaking in the obligatory practical design module access to equipment needed for prototype production or use a wide range of equipment in the context of consultancy projects.

An important point regarding advanced equipment was raised by the head of the Learn programme at the Waag Futurelab. She underlined **the importance of providing teachers and other potential users with relevant instructions and training – both with regard to the use and maintenance of costly equipment**. Otherwise,

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there is an increased risk that equipment is available but not used, either because there are too few individuals knowing how to use it, or because it is broken and there is not enough expertise to fix it.

Although there are slight differences between the educational institutions examined in this case study, **their applied research activities are generally financed through internal funding stemming from public core funding of the institutions**. Other sources of income may stem from fee-for-service work, as exemplified by the cases on Saskatchewan Polytechnic and the Design Factory at the Singapore Institute of Technology. Furthermore, most of the educational institutions featured in this study partly source funding for applied research projects by applying for funds from government grants or charitable trusts, as well as by engaging in partnerships with industry and research collaborations with universities.

III.III Approach to applied research and innovation

Findings from the case studies show a range of similarities between the examined educational institutions that engage in applied research. All of these **conduct applied research to find solutions to real-world problems and produce concrete results**. Findings of the case studies suggest that the examined educational institutions primarily work with business partners on applied research projects, while also collaborating with research institutions – and, in some instances, public organisations and NGOs.

At Saskatchewan Polytechnic, for instance, the primary goal of applied research is delivering innovative solutions for business partners. The institution fosters industry innovation by assessing the needs of industry partners, as well as developing and testing developed solutions or products for enhanced market viability. Saskatchewan Polytechnic is typically in close engagement, also financially, with business partners throughout applied research projects. Students at the institution can participate in such projects voluntarily, for instance at part of their capstone projects, or as hired student research assistants receiving hourly wages. Likewise, students can act as research assistants in applied research projects conducted by Holmesglen Institute or the Design Factory at the Singapore Institute of Technology (e.g., in connection with fee-for-service design consultancy work for private or public clients). Management and teachers across these institutions agree that giving students the opportunity to get involved in applied research contributes positively to their learning, for instance, by providing them with industry contact and insights as well as the opportunity to apply previously acquired knowledge.

While the level of student involvement in applied research projects differs among the examined education institutions, they all **work with the integration of research outcomes into offered education programmes**. This means that students benefit directly from knowledge created within applied research projects Furthermore, most of these institutions **focus on a problem-based learning approach as a teaching and learning strategy**. This means that students regularly get to learn and develop skills by working on specific cases and finding solutions to problems, which can be of a theoretical nature, but often are real-world problems brought in by industry or community partners of the educational institutions.

The project Green Code at the Copenhagen School of Design and Technology is a good example of problem-based learning in collaboration with a business partner. In the project, students of the multimedia programme were tasked to support sustainable web design by developing a CO_2-calculator to measure the carbon footprint of company websites. Students also had to design a graphical format that easily communicated results.

Further examples are related to the Design Factory at the Singapore Institute of Technology (SIT), which supports staff from different faculties with the facilitation of two design modules that all undergraduate students at the university of applied sciences have to pass. While the first design module focuses on theoretical knowledge and an introduction to design thinking, the second module is of a practical nature and tasks interdisciplinary groups of students (from at least two different educational programmes) with applying knowledge gained during the initial

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design module. As part of the practical design module, SIT students from the academic cluster Business, Communication and Design produced marketing videos for a business client, while students from the Health and Social Sciences cluster designed a wheelchair rack for use in an elderly care home located in a high-rise building. Interestingly, students participating in the second design module are given a significant degree of freedom in terms of what problems to focus on and how to address them. Often, students can work with a problem of their choice – as long as it is relevant within the context of their eudcational programme – and are free to chose the specific tools and equipment they want to use when developing prototypes of a possible solution.

Additionally, the Design Factory also collaborates with business partners on the upskilling of academic staff involved in applied research. In line with its increased focus on sustainability, the innovation centre has recently worked together with a private design consultancy to provide SIT staff with training in circular design.

Another main finding from the case studies is that **organisations conducting applied research make an active effort to identify current and future research opportunities**. In the examined educational institutions, it is either the management of applied research programmes or the teachers and other staff directly involved in conducting research that build and maintain relationships with businesses and other external stakeholders, for instance through participation in conferences and research alliances, as well as generally engaging in networking. At the Holmesglen Institute, for example, the expansion of industry and community partnerships to promote applied research and innovation is part of strategic efforts to establish a research culture at the institution.

As it is quite distinct from the examined educational institutions, it should also be highlighted how the Waag Futurelab works with applied research and innovation, particularly in the form of maker education. At the Learn division of the Dutch NGO, focus is on providing learners with opportunities to engage in creative and critical thinking through an iterative process of creative thinking, designing, and 'making'. It is noteworthy that the emphasis is not necessarily on reaching tangible outcomes, but rather on the process. The Learn division at the Waag Futurelab seeks to promote a maker mindset valuing curiosity, resilience, creativity, and problem-solving skills. By combining maker education and its so-called 'open schooling' approach, the Learn division at Waag Futurelab has developed a distinct educational paradigm. It extends beyond traditional classroom learning, to create a more integrated, community-oriented and experiential learning environment, as it encourages collaboration focusing on real-world problems between schools, communities and other stakeholders to promote lifelong learning and active citizenship.

Last but not least, the partners in the Challenger project seek to ensure gender equality in the development of a new framework for the integration of applied research into VET. On this background, it is noteworthy that **findings from the case studies have produced little evidence of a focus on gender** in the examined organisations' applied research activities. None of the case organisations have relevant policies or strategies regarding, for instance, gender equality in terms of who is leading or conducting applied research projects, or the inclusion of gender perspectives in such projects. However, management of the applied research programme at the Copenhagen School of Design and Technology points out that several of the institution's applied research projects have addressed gender issues. Further, the head of the Design Factory at the Singapore Institute of Technology highlights that all of their design and innovation activities are implemented with regard to ethical considerations, including those related to environmental sustainability, diversity, and gender equality. Students of the mandatory design module, for instance, are trained to take these issues into account when developing solutions to specific problems.

III.IV Impact

Outcomes of the case studies related to impact clearly underline the benefits of applied research. Lessons learnt from the examined educational institutions show, for instance, that t**eachers involved in applied research can**

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learn about industry practices and processes, while getting insights into the latest technologies implemented in different sectors. Teachers also gain valuable research skills from managing and executing applied research projects. At Holmesglen Institute, faculty staff express that staying up to speed on the latest industry trends and technologies can be hard when one is also having teaching responsibilities. Participation in applied research projects is, thus, a great way to stay close to evolving needs and advancement in the industry. This is echoed by representatives from Saskatchewan Polytechnic, who underline that applied research activities contribute to the development of research capabilities and professional growth of faculty members, partly because acquired industry insights enable them to enhance the relevance and quality of their instruction.

Similarly, **when conducting projects for industry or community partners, students are able to learn about priorities and demands of different stakeholders, including employers**. Like teaching staff involved in applied research, they also benefit from being exposed to advanced equipment and technology that may be applied in an innovation project. At the same time, students get a broader understanding of the research process and the skills it requires when conducting applied research.

Furthermore**, participation in applied research projects stimulates a wide range of skills among students**. When working as part of a project team or with business contacts, for example, students develop collaboration and communication skills. The focus on solving specific, real-world problems by developing concrete solutions promotes creative and critical thinking, practical and problem-solving skills, as well as self-directed learning. As pointed out by interviewees from the Holmesglen Institute, students also learn to be flexible and curious – abilities that are considered to be highly relevant in the changing labour market. Interestingly, it is a strategic focus at the Singapore Institute of Technology to produce graduates with the necessary skills to act as intrapreneurs in their future workplace, rather than developing entrepreneurs who start their own businesses. This means that senior management prioritises the development of graduates that can bring innovation into companies.

According to researchers from Saskatchewan Polytechnic, **experiences gained by students throughout applied research projects are highly beneficial for their future employment prospects**. This is underlined by the fact that both Saskatchewan Polytechnic and the Copenhagen School of Design and Technology have experienced that former students, who had been involved in applied research projects, were subsequently hired by partners in these projects. At the Design Factory at the Singapore Institute of Technology, they are also aware of this dynamic. The Design Factory arranges a yearly Industry Day, where students showcase the results of their design projects to interested businesses and organisations.

Another lesson learnt is that **applied research projects implemented by educational institutions can have a positive impact on a range of external stakeholders**, both at the local and regional level. As described in case study D, Saskatchewan Polytechnic has had a significant impact on the Province of Saskatchewan by providing practical solutions, supporting technological advancements, fostering industry collaboration, and addressing societal challenges. Through its applied research activities, the institution has provided businesses with advanced infrastructure for machining, manufacturing, and additive manufacturing. Among other things, this has helped to increase the innovation capacity of small- to medium-sized enterprises. **Enterprises with more limited resources may particularly benefit from applied research partnerships with educational institutions** as they give them access to research capacity and prospective employees in the form of students, as well as to advanced equipment and technology that they otherwise may not be able to afford.

Further examples from the case studies underline, how applied research activities can have a positive impact on the wider community. The Design Factory at the Singapore Institute of Technology has conducted applied research projects based on design thinking for a diversity of stakeholders. These included the National Council for

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Social Service in Singapore (NCSS), who wanted a solution to better match participants in corporate volunteer programmes with social service organisations in need of additional hands. Another Design Factory client from logistics was provided with a design solution for storing fragile supplies in warehouses that are not climate-controlled in the context of mitigating the shortage of fragile goods during the Coivid-19 pandemic. Additionally, Saskatchewan Polytechnic has worked with community partners, for instance, the Saskatchewan Centre for Patient-Oriented Research (SCPOR). In the project with SCPOR, researchers from the institution were involved in including a greater diversity of perspectives in healthcare research, such as those of indigenous communities, recent immigrants, and refugees.

III.V Systemic obstacles

Given the lessons learnt on resources needed for conducting applied research, it is not surprising that **most case organisations point out systemic obstacles related to funding, particularly with regard to necessary investments in facilities and staff**. This is in line with findings highlighted in section III.II underlining that applied research is costly. It requires advanced equipment and facilities, highly-qualified staff with research expertise and industry insights, as well as the upskilling of teachers – if they are to conduct applied research projects.

Further examples of systemic obstacles are linked to the availability and development of educational staff. VET institutions wanting their teachers to get involved in applied research may need to ensure that other teaching staff can cover in the classroom for teachers occupied by project work. Additionally, **there are issues related to the changes in teacher responsibilities and working hours that arise in line with the shift from traditional teaching to involvement in applied research**. At the same time, some teachers may be motivated and willing to do research or provide students with guidance on their innovation projects outside of their typical working hours, while others may not. At Saskatchewan Polytechnic, management underlines that it can be burdensome to apply for needed grants and funding, while faculty members also can struggle to see the incentives to (temporarily) leave teaching for being part of an applied research project. It can further be added that some of the case organisations highlight difficulties in recruiting adequately skilled teachers and other staff for supporting or conducting applied research activities.

At the Copenhagen School of Design and Technology, management emphasises that they sometimes struggle to engage businesses in applied research projects due to a lack of financial incentives for them to participate. Representatives of the Design Factory at the Singapore Institute of Technology do not experience difficulties in establishing industry collaborations, partly because public-private partnerships are rather common in Singapore. However, they underline – alongside other case organisations – that **problems can arise in relation to intellectual property rights and ownership of project outcomes** when educational institutions collaborate with industry partners on applied research.

At Saskatchewan Polytechnic, they have taken an interesting approach to addressing the discussed obstacles to industry engagement in applied research projects. It includes active communication of applied research opportunities and a focus on the value that potential industry partners can get out of conducting applied research projects with the institution. Most noteworthy, Saskatchewan has taken the strategic decision to let industry partners retain the rights to all intellectual property resulting from projects to increase their incentive to participate.

Other potential systemic obstacles to the integration of applied research into VET have been pointed out by interviewees from case organisations. These include **difficulties with adapting curricula** – for instance in countries where this is difficult to achieve – and incorporating skills and activities that enhance the innovation capacity of learners. Further, experiences of the Waag Futurelab with maker education show that **activities**

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meant to promote innovation skills among students are easier to implement in smaller groups. This represents a challenge in terms of upscaling such activities to larger groups of students.

A final key finding from the conducted case studies underlines the importance of having a strong and motivated management when trying to integrate applied research within educational institutions. **In most case organisations, management has taken a strategic decision to prioritise applied research activities and to allocate the resources needed for conducting them**. Additionally, some of these organisations have benefited from active and highly-engaged heads or directors of applied research programmes that, for instance, have focused on establishing and maintaining industry collaborations or on creating institutional cultures where it is viewed positively when educational staff partly step back from teaching obligations to take on applied research.

III.VI Concluding remarks

The partners in the Challenger project are meant to build on the lessons learnt presented above in their work with developing a new framework for the integration of applied research into VET. Some approaches to managing and conducting applied research discussed in this study will certainly be easier to adapt and integrate than others, which is partly due to the different national contexts and education systems that the examined case organisations operate in.

Nonetheless, the outcomes of this best practice study underline the importance and benefits of applied research – both as a driver of innovation and a teaching and learning strategy. On this background, the study results should provide valuable inspiration for the further efforts in the Challenger project.

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