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Generating Real-World Impact from Academic Research: Experience Report from a University Impact Hub

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ABSTRACT

This paper presents an experience report of Digital Creativity Labs (DC Labs), an ‘impact hub’ created at the University of York in the UK. The impact hub is dedicated to fostering impactful collaborations between practitioners and researchers in the world of games, interactive media and the rich space in which these converge. In this paper we describe how the impact hub works and the activities undertaken to build a culture of academic entrepreneurship that allows academic researchers to understand the goals of external partners and align with them. We also present some illustrative case studies before proposing initial lessons learned from experiences of the Lab. Multi-disciplinary academic teams can generate excellent impact, but this doesn’t happen automatically. A culture of entrepreneurship is needed, and opportunities must be created for researchers to tackle problems jointly. Effort must be put into maintaining collaborations with partners.

CCS CONCEPTS

- **Applied computing** → **Arts and humanities; Education;**
- **Social and professional topics;**

KEYWORDS

research impact, university-industry collaboration, inter-disciplinary research

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1 INTRODUCTION

In this paper we present the academic perspective on strategies for closing the gap between academic research and industrial practice. We describe an ‘impact hub’ based at the University of York in

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the UK, a Laboratory dedicated to fostering impactful research collaborations and generating real results for practitioners while enabling high quality research outputs. In this case the impact hub, ‘Digital Creativity Labs’ (DC Labs), specialises in games, interactive media and the rich space in which these areas converge.

Academic researchers are expected to train for many years to develop their expertise. Each academic discipline has highly specialist concepts, terminology and techniques which are not immediately accessible to researchers from other disciplines. Furthermore, each discipline has very different expectations regarding collaboration, publication, impact, ideas generation and academic behaviour generally. Consequently, researchers in different disciplines can become isolated in discipline-specific ‘silos’. However, the discipline-specific silos do not map neatly to the requirements and needs of real delivery projects. Instead, ‘real-world’ projects frequently require inputs from many different specialists and functions during the activities associated with conception, design, development and operation. To overcome this barrier, DC Labs has created a multi-disciplinary research culture which emphasises academic entrepreneurship and external engagement. This approach has fostered real-world impact for academic work, by helping researchers understand the goals of industrial practitioners much more effectively. The observations in this paper constitute an experience report presented from the academic perspective, highlighting activities found to be effective at DC Labs for establishing multiple successful collaborations with practitioners.

2 BACKGROUND

Collaboration between academics and practitioners can benefit both parties. Firms which collaborate more with universities produce more innovative products [21, 29], and regions with entrepreneurial universities see more innovation regionally [22]. Meanwhile, academics who actively engage with industry produce higher quality research outputs and tend to obtain higher funding [19].

However, academics and practitioners have different goals, motivations and cultures [3, 8, 9, 20, 23] as well as different expectations for the timescales and openness of delivered results. These differences can hamper co-operative endeavours [29]. Gaining a better understanding of each others’ fields, goals and practices appears to help. For example, academics who already have industrial experience, entrepreneurial training or experience of collaboration are more likely to be entrepreneurial or collaborative [1]. Successful collaboration between industry and academia is associated with high levels of trust [5, 6] and strong personal relationships [18, 22].

It's important to note that 'industry' and 'academia' are themselves not monolithic. There is substantial variation between different academic disciplines, on the one hand, and between different non-academic enterprises, on the other. If they are to be successful, approaches to fostering collaborations will need to take this into account.

2.1 Understanding multi-disciplinary academic culture

DC Labs has been established in a research climate in the UK which requires academics to explicitly articulate the impact of their research [7]. 'Impact' is defined in various ways (e.g., [25]), but most definitions include positive effects on culture, society, and/or the economy. Allocations of UK research funding are influenced by a performance-based funding system (the Research Excellence Framework, or 'REF') which requires universities to submit case studies illustrating the impact of their research. Statements on impact are also required in applications for research grants. These assessments have resulted in collection of data illustrating the impact of recent UK research, and analysis of this data shows that inter-disciplinary research is particularly effective for achieving real-world results. In the most recent national assessment, 87% of case studies submitted by universities involved multiple disciplines [2].

Recognition that multiple disciplines are needed for successful project delivery brings academia in line with commercial sectors. For example, working in cross-functional teams is known to lead to improved innovation in manufacturing and product design [11, 16]. Meanwhile cross-functional teams [12, 13] have become a key pillar of agile software development methodologies. In a multi-disciplinary team, misunderstandings and implicit assumptions are surfaced and challenged as the team moves towards developing a shared understanding, which leads to improved business outcomes [14, 15]. For these reasons, DC Labs has been built on the conviction that a multi-disciplinary research culture is the first step towards facilitating better collaboration with external enterprises.

DC Labs is dedicated to studying the space of convergence defined by games and linear media, by understanding how aspects of play and storytelling could be combined and better exploited in mediated communication and interaction in various sectors of our lives, including entertainment, culture, education and well-being. The Lab's R&D agenda is aligned with that of the video game and media industries, but is tightly connected with other industries, cultural sectors, government and and third party endeavors which have interest in this space. This includes schools, heritage organisations, social enterprises, environmental charities, architects, performing arts venues and artists and film and television businesses. The Lab has its roots in computer science and interactive media, and draws in numerous other academic disciplines that are needed to contribute to these industries, including specialists in design, psychology, biology and health sciences, education, heritage and history, archaeology, sociology, language and linguistics, music, electronics engineering and theatre and film. The intention was to create a Lab which is multi-disciplinary (in which multiple disciplines work side by side) or even inter-disciplinary (in which staff integrate research questions and methods from multiple disciplines).

2.2 Aligning with practitioner culture

On the other side of the equation, firms and other non-academic enterprises also exhibit wide variance in their needs, goals and cultures. Firms may have widely varying strategic end-goals in mind when they undertake collaborations. It's important to be explicit about the nature of these end-goals so that all parties in the collaboration can take this into account.

Setting up partnerships is not easy and there is an initial effort overhead [8]. Larger firms may find it easier to absorb this initial investment. In contrast, SMEs typically have constrained resources, fewer staff and less ability to invest in long-term developments [27]. When setting up a collaboration, smaller firms may even see an initial reduction of innovation outputs before seeing an increase [26]. Despite these challenges, academic collaborations can provide SMEs with sources of idea generation, research expertise, specialist development capabilities and/or horizon scanning that would not be otherwise available. In fact, many former studies have linked SME university collaborations with innovation success [4, 28].

The same factors that make universities potentially valuable partners for SMEs also apply for other types of enterprise, such as charities, social enterprises, schools, museums and theatres, public sector, and other non-profits. In many cases, innovative technology is important for these enterprises in order to stay relevant, improve efficiency, and maintain quality of outputs, although resources for investing in innovation are slim. Motivations, internal capabilities and capacities, and end user characteristics vary between commercial firms and non-profit enterprises, and priorities and goals for many of these enterprises may not be commercially-driven. Academic partners need take time to understand the specific expectations and goals of their non-academic partners if collaborations are to be successful.

A majority of the firms in industrial sectors relevant to DC Labs (such as video gaming, film and theatre) are SMEs or microfirms. Therefore, although DC Labs can and does collaborate very successfully with large enterprises, DC Labs has created an academic culture that facilitates collaboration with small enterprises alongside large firms.

3 IMPACT HUB CONCEPT

The Digital Creativity Labs (DC Labs) was founded in 2015 at the University of York as an £18m initiative, an impact hub with initial funding from three UK research councils, four universities and over eighty non-academic partners. The aim is to ensure that researchers working in fields relevant to games and interactive media can maximise the full impact of their research, through fostering connections between researchers and practitioners. Practitioners collaborating with the lab includes industry, government, non-profit communities, the third sector and the general public.

3.1 Impact hub structure

DC Lab staff are shown in Table 1. In order to create an effective inter- and multi-disciplinary culture, DC Labs employs full-time post-doctoral researchers. To date, nearly 30 post doctoral researchers are, or have been, employed in the lab on a wide mixture of projects. In addition to computer science and interactive media, researchers span diverse fields such as education, electronic

engineering, social science, business & management, heritage, archaeology, life sciences and design.

The Lab also employs full-time software engineers, most of whom have industry experience, as well as a marketing specialist, administrative support and full time manager. In addition, two full time PhD students have been funded so far, with two other positions currently available for application. All Lab staff are co-located in an open-plan space. The Lab also plays host to many others, including visiting academics from other institutions, interns, taught students working on summer projects and visiting practitioners.

In addition to core staff, many academics from around the university maintain links to DC Labs, through a variety of mechanisms, including co-supervising PhD students or summer school students; attending joint research days, talks and sandpits; and generating joint project proposals. Academics actively collaborating on explicit projects are shown in Table 1, but many more participate in informal links in addition to this.

3.1.1 Management and strategic direction. The Lab's primary links and strategic leadership team sit with the Department of Computer Science (CS) and the Department of Theatre, Film, Television and Interactive Media (TFTI). A Director provides operational and strategic leadership, and a local management team consisting of the Director, Lab manager, two senior research fellows and senior software developer provides local management. A Strategy Board, consisting of academics representing relevant research themes, provides strategic input. Further strategic advice is provided by an Advisory Board, with representatives from external partners and stakeholders, which meets at long intervals to hear updates and to provide feedback and suggestions. External feedback from practitioners helps to ensure that the Lab's direction and strategy is aligned with the needs of the wider economy and society.

3.1.2 Spoke sites. DC Labs is headquartered at the University of York, but it also fields 'spoke' sites, which provide academic links and support for post-doctoral researchers and academics working on related topics at four other UK universities: Queen Mary's University of London; Falmouth University; Goldsmiths University; and Durham University. The existence of spoke sites allows all five sites to maximise the value of their local network, by pooling contacts local to each university with the general DC Labs community.

3.1.3 External links. The Lab maintains good relations in various ways with over 80 relevant external organisations, including large and small, commercial and non-commercial. Many are local to DC Labs' home region of Yorkshire. At any one time, many of these organisations are working actively with the Lab on collaborative projects, events and proposals. Collaborations that are local are particularly important for smaller enterprises, which have fewer resources to invest in collaboration with distant partners.

3.2 Practice-based research

The philosophy of the DC Labs is to implement 'practice-based research'. Projects undertaken at the Lab typically (although not universally) aim to deliver as a priority a prototype, normally a working prototype such as a minimal viable product. Reflection and learning, data collection and research follow on from this. Effectively the Lab uses researcher and/or professional developer

Table 1: People who have been actively involved in the impact hub during its operation

| | |
|---|----|
| Post doctoral research staff | 29 |
| Research fellows | 5 |
| Full time software developers | 4 |
| Professional support staff | 6 |
| PhD students | 2 |
| Full time academic staff (includes Principal Investigators (PIs), Co-Investigators (CIs) & associated academics | 23 |

expertise to deliver working (or Wizard of Oz) prototypes developed collaboratively, and gathers feedback and real-world problems to fuel research in exchange.

The Lab advances research through a portfolio of projects, which vary significantly in size, funding sources and technology maturity. Some of these projects are funded entirely by the DC Labs, but most are co-funded with external partners, and some are supported entirely through external funders. In particular, the Lab has the ability to invest staff time (with a researcher, software developer, or both) to kick off small proof-of-concept projects very quickly. This can be a particularly powerful tool for supporting collaborations with SMEs, microfirms or non-profits. Issues of IP are dealt with on a project-by-project basis.

The DC Labs is currently primarily a research lab, and as a result its research staff have lighter teaching loads. Some of the Lab's research projects influence teaching activities, and both researchers and academics supervise undergraduate final year and summer school projects.

3.3 Creating a culture

Individual Lab members have different backgrounds and separate projects. To create a team ethos, Lab meetings are held every week, adopting a format similar to a daily standup, where each staff member (including researchers, software engineers, academics and support staff) briefly summarize what they are currently working on and planning to work on in the next week, current obstacles, and any news or events on the horizon. Individual Lab members often offer suggestions to each other at the meeting. In addition, half-day or full-day 'forum' events are held every 6 weeks. Some forums provide training, some involve hearing more about each others' work, or bring in expertise from outside the Lab. Finally, there have been a number of 'strategy day' events throughout the Lab's lifespan where all members of the Lab work together to co-create and feed back on the Lab's future strategies, allowing perspectives from multiple disciplines to comment on strategic direction.

In addition to building a multi-disciplinary team culture, the Lab also works on building an entrepreneurial mindset. Training opportunities made available to researchers include media training and innovation bootcamps. One year after the Lab's initial creation, a one-week course on business innovation was made available to all the members of the Lab, covering common commercialisation topics such as venture capital funding, pitching, and building on ideas for development. At the culmination of the week, researchers

pitched their ideas competitively to win seed funding. Two major projects were generated from this event, Gaming Grammar (see Section 4.2) and Weavr (see Section 4.1).

Recruiting new potential collaborators requires exposure, to increase the chance of discovering each other. The Lab culture therefore emphasises engagement and outreach activities. A part-time marketing specialist works with the Lab to aid this work. During the first 4 years of the Lab's life, staff conducted more than 320 engagement activities, including giving talks and keynotes, contributing to or even running events locally, nationally and internationally, as well as editing journals and generating content for magazine and newspaper articles.

Personal contacts and relationships are important to ensure successful collaborations; maintaining these relationships requires an investment of time. Each project follows a structured process to identify potential stakeholders and end-users, and helps researchers design plans to engage them. Periodically the Lab has engaged a part-time staff member to support this activity.

3.4 Benefits of the approach

Just over halfway through the Lab's five year operation, an informal internal review was carried out, in which anonymous comments about the benefits and drawbacks of the Lab's approach were collected from a representative sample of staff¹. The review was intended to inform internal strategy. We briefly summarise high-level themes from the review in this Section and in Section 3.5.

In general, staff find that DC Lab's multi-disciplinary, entrepreneurial approach has been very successful for generating new projects that have impact for external organisations. Ability to work across boundaries was strengthened by co-location in a designated physical space, and many collaborations have been forged because of this.

This outcome is also supported by previous academic studies, which have shown that physical separation makes it more difficult to establish and maintain connections, and that distance affects productivity negatively [24]. During the early stages of collaborative research or R&D projects (for example, while generating, evaluating and elaborating on ideas for new work) serendipitous 'corridor talk' is particularly important. Researchers in multi-disciplinary environments in particular often find that they have implicit assumptions and tacit knowledge from their disciplinary training which is not visible to their peers from other disciplines; surfacing these assumptions is easier when co-located [17]. Internal reviews also suggested that research staff feel that the availability of multiple perspectives enabled them to generate new insights by seeing different interpretations and assumptions. This ultimately inspired new directions and approaches for research projects.

3.4.1 Indicators of successful relationships with external enterprises. Outputs generated by the Labs are dominated by software applications, including the following:

- Echo, a visualisation tool for esports, which has reached thousands of fans watching professional esports tournaments at major international events such as ESL One (see Section 4.1)
- Gaming Grammar, a game to assist schools in the teaching of foreign languages, tested with 42 schools to date (see Section 4.2)
- Viking VR, an interactive virtual reality (VR) exhibit with York Museums Trust based on an archaeological reconstruction of a Viking camp, visited by approx. 100,000 visitors over 6 months (see Section 4.3)
- Mutator VR², an evolutionary artistic VR installation, which allows the user to take part in the experience by granting interactive control of the forms, system dynamics, and environment. Virtual scenes are entirely procedurally generated from mathematical rules and can be morphed continuously from one to the next so that each experience is truly unique. Mutator VR has been experienced by over 40,000 participants at exhibitions around the world, and shortlisted in 2018 for the prestigious Lumen prize in Digital Art.
- 'Cutting Room', a suite of production tools, based on non-linear, object based storytelling and produced in collaboration with the BBC. The software was used by an SME, Symbolism Studios, to create the short-film 'What is Love', an installation at an international arts festival receiving an estimated 700 visitors, which in turn provided the inspiration for the BBC to implement the one thousand episode of BBC Click as an interactive TV programme.

In addition, the Lab's annual Game Jam has been attended by more than 250 students and industry professionals, with one game securing an investment of £30,000 from the UK Games Fund.

3.5 Drawbacks of the approach

Although appreciated by many, it is still difficult to develop and carry out interdisciplinary research and development. Here we describe some challenges which Lab researchers identified in informal internal reviews.

Prestigious publication venues are often highly focused on specific topics. However, different disciplines have different norms regarding how research is conceived, conducted, evaluated, written up and published. As a result, researchers straddling multi-disciplinary boundaries can find it very difficult to plan research in a way that satisfies the expectations of multiple disciplines. This factor was pointed out by researchers in the Lab during internal reviews. It's sometimes difficult to find high-prestige publication venues for multi-disciplinary or inter-disciplinary research, which is necessary for career progression. This is a recognised challenge for multi-disciplinary researchers right across the academic sector.

DC Labs emphasises prototype development and practice-based research. However, a consequence of this approach is that researchers often spend considerable time, supported by software developers, developing the prototypes that can be deployed in real-life scenarios by the non-academic partners. This often has the effect of reducing the time available for producing academic papers. However, prototypes can now be treated as research outputs (for example, in the UK's REF assessments), and, in addition, the significance of the

¹Staff participating in the review consented to use their quotes internally. Only high-level themes have been inductively drawn from that data here, ensuring full anonymity. In line with standard university procedure, ethics clearance was not required for this internal staff survey.

²<http://mutatorvr.co.uk/>

papers that result from the research work is enhanced by the DC Labs practice-based approach.

Work in DC Labs has traditionally been organised as a portfolio of projects, with separate researchers driving largely separate projects. This has worked well in terms of supporting career progression, allowing researchers to develop ideas that they are passionate about. However, it does mean that the Lab is a multi-disciplinary environment (researchers work in their own disciplines, but collaborate on joint projects) rather than truly inter-disciplinary. In the future DC Labs aims to experiment with different ways of building up ‘connective tissue’ between projects, to test whether this is linked to more positive outcomes, or whether the current multi-disciplinary approach is sufficient.

4 CASE STUDIES

In this section we present some brief case studies illustrating how DC Labs’ approach has helped to align researchers with the needs of practitioners, and to create projects that satisfy both academic and non-academic partners’ goals.

4.1 Weavr: A commercial consortium

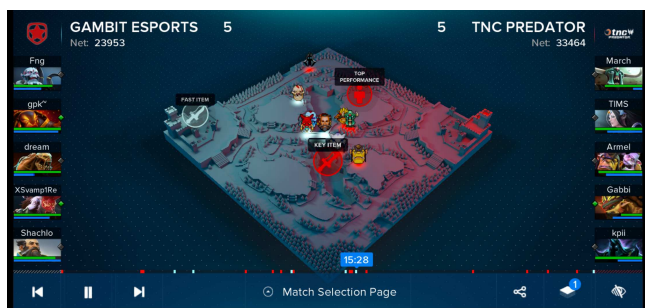


Figure 1: Screen shots of the Weavr Dota 2 Companion app

One of the largest projects generated from DC Labs is the Weavr project³. Weavr develops novel AI and data-driven production tools and audience-facing experiences used in the coverage of live esports. Esports are video games played competitively and commercially for audiences in physical venues such as sports arenas, and streamed live worldwide. It is a rapidly growing market, with global audiences exceeding 450 million people.

The initial ideas for Weavr were generated by DC Labs researchers at a full-time week-long business innovation course, which included training in entrepreneurship concepts and activities. The initial idea was developed and elaborated subsequently and went on to win two applications for strategic innovation funding. This allowed the lead researcher (a computer scientist with a background in HCI and digital exhibits) to recruit a commercial software developer to work on a prototype. The lead researcher worked with diverse partners to develop ideas while prototyping. Feedback initially came from academics in sociology and psychology, but also keen players of Dota 2 and esports consumers, and later from commercial firms working in relevant areas.

³<https://weavr.tv/>

The result of the prototyping phase was an idea for a product that incorporated VR technology, as well as aspects of machine learning and interactive storytelling, backed by a consortium of firms, from microfirms to internationally-known brand names. The Weavr consortium is now supported by a major grant from the UK’s innovation funding agency, Innovate UK, with a mixed academic-commercial R&D team.

Software products developed by Weavr include the Echo Suite, which allows esports viewers to experience immersive, highly interactive cross-reality narratives and data-driven stories surrounding live gameplay. Echo has been integrated into production tools adopted by leading esports content producers, and has been experienced by thousands of viewers to date. During major esports tournaments the development team has released new versions of the application, while the research team have been able to collect and analyse feedback from thousands of users. For commercial partners Echo/Weavr creates meaningful and personalised mixed-reality experiences for esports and sports fans, powers the creation of data-driven content, and opens up commercial opportunities for brands and teams. Meanwhile, researchers have been able to analyse the data to publish novel research findings.

4.2 Gaming Grammar: educational technology for schools

Gaming Grammar⁴ is an educational game designed to aid language teaching primarily for school pupils aged 9-14. It brings together principles for presenting and practising grammar, alongside gamification to create an engaging and effective platform for teaching grammar in a foreign language. The initial idea built on the findings of educational research conducted by the lead researchers. A week-long innovation training workshop organised specifically for DC Labs research staff provided the opportunity for one of the lead researchers (a DC Labs researcher and a specialist in language education) to expand on the initial idea, establishing the business case and the steps needed to bring the idea to life. The workshop culminated in a competitive pitching event to win a small amount of seed funding, which was won by the Gaming Grammar idea.

This seed funding enabled the team to develop a small prototype, based on a simple game design and a single language (in this case, French), as a proof of concept. Initial play-testing with children and adults demonstrated the potential of this tool and the appeal for language learners and teachers. With software development support from the DC Labs, the initial prototype was expanded to incorporate practice of a wider range of grammar features. The project worked with an alliance of local schools, who were interested in the game’s potential to support language learning and teaching, to get feedback from both teachers and pupils on game design and evaluate the effectiveness of the game for learning.

As an educationalist and applied linguist, the lead researcher did not have a background in game design or software development. However, through their work with game design and software development experts within the DC Labs, they were able to develop an understanding of the game design process and the technical requirements of building an educational technology tool.

⁴<https://www.digitalcreativity.ac.uk/creations/gaming-grammar-game>

The lead researcher won a three-month fellowship from the UK's 'ICURE' program⁵, funded by Innovate UK, which runs a twelve week course consisting of commercialisation training and constant contact with potential users, partners or customers to generate feedback. Armed with the feedback, further funding was obtained as part of the Department of Education's National Centre for Excellence in Language Pedagogy. This facilitated the recruitment of a commercial software engineer to develop the game further, deploying it in two additional languages (German and Spanish) and putting the technical requirements in place to allow the game to be rolled out to schools.

The expanded game, now supported by a full time developer and deployed to a number of test schools, is proving to be an effective and motivating teaching and learning tool. It enables pupils to engage in more autonomous learning, whilst allowing teachers to track their learners' progress. Large-scale, classroom-based data gathered through gameplay gives a much more detailed understanding of the children's learning than has previously been available from such trials. The game is designed to be readily adaptable to other languages; it has already been deployed in three languages and could be expanded, for example, to the teaching of English as a Foreign Language (EFL). The project has been able to take into account the needs of the external partners (in this case, schools, teachers and pupils) to align with their goals (improved educational outcomes for learners and an effective and efficient teaching and progress tracking tool for teachers). Meanwhile academic goals are satisfied by generating rich data on language learning through games.

The Gaming Grammar project now forms part of a larger investment of £2.17 million from the UK's Department for Education National Centre for Excellence for MFL Pedagogy.

4.3 VikingVR: A cultural heritage collaboration

One of the first DC Labs projects, Digital Narratives in Archaeology and Heritage (DiNAR), delivered a VR exhibition in partnership with the York Museums Trust. The VikingVR was designed to engage a public audience of all ages and launched as part of the 2017 'Vikings: Rediscover the Legend' exhibition at the Yorkshire Museum⁶. Deploying cinematic techniques, and using Viking period Norse and Anglo Saxon language throughout, the animated scenes include elements of Norse mythology and contemporary storytelling to create integrated immersive narrative experiences based on actual archaeological evidence relevant to the Winter Camp of the Viking Great Army at Torksey [10], near Repton, UK.

The structure and ethos of the DC Labs greatly expedited the formation of a partnership between academic and SME collaborators. The projects leads, academics from the Archaeology and Theatre, Film, TV & Interactive Media (TFTI) departments, were already members of the DC Labs' team of researchers. Funding for the project was already in place via the DC Labs grant itself. The Yorkshire Museum was part of the extended DC Labs network from early in the DC Labs life and was instrumental in suggesting the Viking theme for the project. Archaeologists at the University of York then identified Torksey as a suitable case study. Expertise

from multiple disciplines and specialisms, from both partner organisations, was drawn on during the design and development stages. This included academics from Archaeology, TFTI, Electronics and English specialising in game design, electronics, historic languages and museum studies, and Yorkshire Museum's curation, digital engagement, education and visitor management teams.



Figure 2: User testing the Viking VR headset

The VikingVR experience was developed with ease of use and cost of equipment in mind, as well as future re-use and extension. The design team experimented with Google Cardboard, which offered a convenient and inexpensive platform for developing an immersive experience. The Museum intended to make the VR installation available to the general public visiting the site, which meant that the device for delivering the experience had to be extremely robust, and easy to use. It also had to be readily used by many hundreds of people a day. A conventional headset with its headphones and head strap design is relatively time-consuming to put on and take off, which would restrict the numbers of people able to experience the installation. It is also relatively intimidating to people who have never tried a VR headset before. A new headset device was therefore designed to hold a phone running Google Cardboard. The headset was wooden, emulating a Viking design found on one of the artefacts from Torksey (a prototype is shown in Figure 2). It had small speakers built in at ear level and did not require a headstrap: users could simply hold it up to their face to experience the VR. In order to extend the impact of the VikingVR beyond the walls of the Yorkshire Museum, several digital resources were released under open license during the exhibition. Knowledge accumulated through the VikingVR project was leveraged to develop an immersive experience delivery 'toolkit' to be used by other SMEs within the cultural heritage sector and funded via the UK's Arts and Humanities Research Council (AHRC) funded Digital Creativity for Regional Museums project.

The installation was visited by approximately 100,000 visitors over 6 months, 70% of whom had never used virtual reality before.

⁵<https://icure.uk/>

⁶<https://www.yorkshiremuseum.org.uk/exhibition/viking-rediscover-the-legend/>

5 LESSONS LEARNED

We have refined some key findings from the DC Labs operation over 4.5 years to date, based on informal discussions with staff across the lab and reflecting on initiatives or activities that have worked well for the DC Labs. We summarise them here.

5.1 Facilitate multi-disciplinarity

In DC Labs, this was achieved through:

- Co-location in a shared space. This is a double-edged sword; researchers sometimes find co-location a source of distraction. However, they also rate co-location as valuable, as it results in many serendipitous conversations, and exposes researchers to new perspectives, that in turn lead to new ideas. To underline the point, DC Labs spoke sites have found it harder to maintain the same team ethos, due to the greater difficulty of maintaining regular contact across distances.
- Building a team ethos. It is particularly challenging, but also particularly important and rewarding, to create a team ethos when everyone in the lab has a different project and different training. Regular standups are helpful, giving everyone a chance to hear what colleagues are working on and feel involved in each other's projects, offer suggestions and celebrate each other's achievements. Other means to achieve this include regular research forums, dedicated meetings to refine and re-enforce the team ethos, management leading by example, social and informal events, and supporting personal expression and development.

5.2 Embed a culture of academic entrepreneurship

Embedding a culture of entrepreneurship in a research lab has helped DC Labs achieve impactful results. The following techniques were used to achieve this.

- Innovation training for researchers has been immensely successful for DC Labs. DC Labs employed a format of a week-long workshop, aimed to be attended by almost all researchers in the Lab. The workshop involves training in basic concepts important for the commercial sector, such as generating and scrutinising commercialisable ideas and pitching to investors. Two of the lab's most successful projects have benefitted greatly from this exercise, either through providing a forum which allowed researchers to develop and take forward their existing ideas, or by providing a platform for generating innovative new ideas.
- An Advisory Board comprising representatives from external organisations, both commercial and non-commercial, helps to ensure that the needs and views of practitioners are visible and influence strategic decisions, as well as ensuring that the challenges and priorities identified by the hub are timely, significant and aligned with societal, governmental and industrial needs.
- It's important to create opportunities where researchers with diverse backgrounds are working together on tackling cross cutting challenges. This doesn't necessarily happen naturally; for example, in the Lab, researchers tend to be working

on their own separate projects on a day to day basis. Events such as workshops and sandpits, tackling cross-cutting challenges and real-world problems, help create opportunities for researchers from different disciplines to work together, potentially with external partners.

5.3 Build relationships

Large multi-nationals, charities, local SMEs, and educational organisations all have real-world needs, but their working processes, values and key goals will be different, and different activities are appropriate for staying in touch and keeping collaborations active.

- Effort is needed to maintain relationships with partners, and this needs to be recognised. The effort required is lower for local connections, especially if they share industrial interests (as partners are likely to meet regularly and informally at local events) than for distant partners, where communications such as conference calls and visits take effort, and often need scheduling.
- A relevant local network is particularly important for SMEs, microfirms and non-profits, which have fewer resources for collaborating with distant partners. Creative industries are an important and recognised sector for the local economy around York and the Lab actively contributes towards a rich and busy local ecosystem. For example, DC Labs staff are involved in relevant local networking initiatives, provide space for events such as game jams, and contribute towards York's arts festival, Mediale.
- The DC Lab's network of contacts relies, like most such networks, on personal relationships and trust. From the academic point of view, trust is built up with external partners through ensuring that the needs of the partner are fully met. Therefore, academics need take time to understand what the external enterprise needs from a collaboration, and ensure that that their needs are met. Partners don't usually expect to work together permanently, but do want to be able to take advantage of opportunities when they arise. Having access to reliable partners (academic or otherwise) that can be trusted to deliver enables firms - particularly SMEs - to respond quickly to arising opportunities. Therefore looking after the needs of partners can help a single partnership turn into a repeated collaboration. This approach is compatible with academics carrying out practice-based research.
- Performance reviews and reward systems for researchers must recognise entrepreneurial achievements as well as academic.
- When initiating a new project, researchers need to consider at an early stage how to assess whether the collaboration will have been successful (for both the academic partner, and the non-academic partner).

6 CONCLUSIONS AND FUTURE WORK

In this paper we have presented an experience report highlighting some key aspects of the operation - for four and a half years - of a research impact development hub, comprising 4 universities and over 80 non-academic partners from industry, government and the third sector. The hub's aim is to ensure that researchers can generate

maximum impact by fostering links with external enterprises. The impact hub has created a work culture that has led to significant impact whilst at the same time allowing researchers to generate high quality research outputs. Key priorities for DC Labs have been to: adopt a practice-based research approach; invest mainly in research and innovation co-created and co-shared with external partners; foster multi-disciplinarity; encourage and develop innovation and entrepreneurship; recognise the value of an invest in outreach and external engagement activities.

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