JULIA HAMILTON, MATTHEW MULLARKEY

ENABLING CITIES TO HARNESS THE FULL POTENTIAL OF THE INTERNET OF THINGS[1]

"As cities move towards connected and smarter infrastructure, we need to ensure that our workforce has a strong understanding of the Internet of Things and its potential to address city challenges."- Jamie Cudden

Jamie Cudden, the Smart City Programme Manager for Dublin City Council (DCC), had just participated in the most recent review of the sensor-enabled smart gully project in Dublin city. Tasked with exploring how technology can help address city challenges to create a 'smarter' Dublin, Jamie wondered why more smart sensor applications were not being identified and deployed by DCC departments. He knew that smart sensors existed in the commercial marketplace for everything that could be measured and believed that most city services could be improved with better, real-time measurement. What he could not understand was why more sensor-enabled connected systems were not being deployed by operational service teams across the city.

Over the last three years Smart Docklands, a smart city testbed in the Dublin Docklands, had facilitated a broad range of projects with DCC staff utilising Internet of Things (IoT) technology. While these projects demonstrated the value of IoT for specific applications – such as blocked gullies [Exhibit 1] and waste management - there still remained a relatively low utilisation of IoT across DCC's operational services. Jamie thought, if IoT is really a better way of addressing these issues, why was there not a mass migration towards its use across the Council?

Through talking with his colleagues, Jamie realised that a major barrier to IoT deployments was a lack of knowledge of what IoT was and how it would help address the challenges the Council was trying to solve.

How would Jamie energise his current and future peers to identify more ways to use technology to connect the city? How would they learn about the power of IoT connected devices? How might each city department generate innovative smart solutions to identify and respond to critical issues with the infrastructure and services of the city?

Jamie had recently attended an 'Introduction to IoT' workshop for DCC staff at Dogpatch Labs. The workshop highlighted that educating the city's staff about IoT could encourage a move towards more sensor driven city operations. With this, he was now faced with the challenge of how best to design and deliver an education programme on a larger scale so cities across Ireland could capitalise on the on the benefits of IoT.

Editor: Grandon Gill

Smart Docklands

In 2018, a smart cities test-bed 'Smart Docklands' was established in partnership between DCC, academic research partners CONNECT [Exhibit 2] and the Enable Research Programme [Exhibit 3].

Smart Docklands is a unique smart city testbed in the heart of Dublin's Docklands. It was a first of its kind in Ireland and globally, where the municipality and academia funded a Project Management Office to play an 'honest broker' role amongst government, the tech and start-up community, business owners, universities, research centers, and citizens of Dublin.

This innovative 'quadruple helix model' not only successfully engaged collaboration between different stakeholders, but also secured strategic global partnerships with Google, IBM, AT&T, Accenture, Dense Air, Microsoft, Vodafone, Autodesk, Mastercard, Intel, and Softbank.

Smart Docklands successfully facilitated and enabled the testing and trialling of smart city solutions. They identified real local challenges and worked with diverse stakeholders to come up with lasting solutions in areas such as disruptive technology, environmental monitoring, waste management, and smart mobility.

The mantra was do not deploy "tech for tech's sake". Through their community engagement programme Smart Docklands worked closely with a diverse range of stakeholder groups including physical infrastructure companies, utility providers, property developers, building owners and local residents to identify challenges which could be addressed through new smart city technology and applications.

These engagements provided Smart Docklands with hundreds of challenges and concerns which informed the direction of new pilot projects across the Docklands Smart City test bed – everything from cycle safety, to better management of waste, flooding alerts, more accessible connectivity options, congestion and water safety issues.

Smart Docklands began facilitating a collaboration between Dublin City Council's operational staff, academics and technology companies to test how technology solutions could address services important to the people of Dublin including flooding, waste management and mobility.

While these projects demonstrated the value of IoT for specific applications - like blocked gullies and waste - there remained a relatively low utilisation of IoT across the Council's broader operational services.

Internet of Things - What's in it for the City?

The Internet of Things (IoT) described a system where devices that collect and transmit data via the internet are connected to a software platform which applies analytics and presents information from the devices in an understandable way. At its most basic level, the system has three components: hardware (the sensor(s) that collected the data), software (a platform which received the data), and connectivity (the process which transmitted the data to the platform) [Exhibit 4].

The development of IoT completely transformed the way systems were able to "detect patterns, make recommendations, and detect possible problems before they occur" (Clark, 2016). Over the prior two decades, Jamie knew that IoT had progressed from being predominantly used in highly specialised industries to becoming a mainstream technology present across a broad range of industries. Many facets of peoples' daily lives would change through consumables such as smart watches, smart cars and smart appliances. The falling costs of developing sensors and storing data, coupled with significant enhancements in connectivity options and computing power, enabled the rapid growth of the industry.

This growth was expected to continue with an estimated "potential economic impact of $3.9 trillion to $11.1 trillion per year" in 2025 (McKinsey Global Institute, 2015).

Traditionally, the main users of IoT technology had been private sector industries such as manufacturing, transportation, agriculture and retail. However, more recently Jamie had seen a transition from a siloed industry specific application towards horizontally integrated systems across a city's infrastructure aiming to create 'smarter' data driven cities. Jamie believed that IoT could be applied across all aspects of the city including automated transport, safety, environmental monitoring, smart buildings and smart lighting. The global movement to create smart cities had seen a huge shift in the customer base for IoT and it was estimated that IoT in city settings could have an economic impact of $930 billion to $1.6 trillion per year in 2025 (McKinsey Global Institute, 2015) [Exhibit 5].

Jamie's role provided him the opportunity to engage with leading industry and academic technology experts across the globe. Over the last decade Jamie had seen the prominence of Internet of Things (IoT) increase as a leading technology that used connected sensors to help automate processes, create new data and address challenges across a broad range of industries.

With the cost of sensors now in the tens and hundreds of dollars rather than thousands, local authorities' ability to invest in IoT infrastructure on a city scale was a more achievable. Installation and maintenance cost for sensors continue to decline as connectivity options such as Low Powered Wide Area Networks (LPWAN) provide better options for connecting wirelessly and using batteries which can last over five years (Deloitte, 2018). This also allows sensors to be deployed in remote areas rather than only urban areas with wired networks.

While overall costs depend on the connectivity option and sensors chosen, "IoT applications have the potential to improve companies' revenue and costs by reinventing the way in which they do business" (Deloitte, 2018). The smart gully project highlighted the potential operational cost savings by redesigning the maintenance scheduled based on the data provided by the gully sensors. The cost of clearing the blocked drains would still be considerably less than the cost of repairing damaged infrastructure and property from flooding.

From studying deployments in city governments around the world, Jamie felt it was evident that IoT presented an incredible opportunity to not only better understand how cities operate, but also how to create operational efficiencies at a more cost effective and scalable way than ever before. He knew that to harness the full potential of a 'smart city' not only required a fundamental shift in the way the city planned, built and operated city services, but also how current and future staff are trained to think.

Those in both strategic and operational roles within local authorities would need to have a strong understanding of IoT. Jamie knew the operational departments would need to know how IoT could be applied and understand the key considerations when looking to deploy and operate those technologies in a city context. Given the nature of the IoT system, each department would also need to be aware of aspects such as connectivity options, security, data privacy, and interoperability. Jamie invited Julia Hamilton from his Smart Docklands team to explore IoT education opportunities.

When surveying the educational landscape both domestically and abroad, Jamie and Julia had seen various IoT education programmes emerging. However, these were predominantly focused on the technical aspects of IoT and were generally specific to a certain industry, e.g., healthcare and construction. Local government staff required a more tailored programme which explored applications and acknowledged deployment considerations in a public setting as these might vary greatly from the needs of private industries.

Addressing Market Gaps

Through the Smart Docklands programme, Jamie had an existing partnership with the CONNECT research centre. Their remit included engaging the public in its research by increasing public awareness and deepening public understanding of key technical concepts in the telecommunications domain. Jamie saw the CONNECT relationship as key to the advancement of the understanding and deployment of the IoT in the city.

With a shared goal of increasing knowledge around IoT for cities, DCC's Smart City Team and CONNECT's Education and Public Engagement Team established a Targeted Project[2] to develop and test the effectiveness of an IoT education programme. It consists of a pilot programme called Academy of the Near Future.

The programme goals were to:

- **Deepen understanding of IoT:** demystify IoT by increasing participants' understanding of a smart city, connectivity options and sensors.
- **Reduce barriers to IoT engagement:** be accessible, removing the technological barriers for people wanting to engage with IoT, and target students in lower socio-economic groups.
- **Upskill the workforce:** provide the tools and knowledge to empower professionals to utilise IoT to solve city challenges.
- **Promote entrepreneurship:** promote the use of innovative technologies capitalising on IoT to address city challenges.
- **Build trust:** foster positive public opinion by building trust in the possibility of technology to address city challenges.

Jamie's team also identified a need for - not only the current - but also the future workforce to understand the potential possibilities that IoT presented. They brainstormed ideas for a number of possible training opportunities and concluded: outreach to secondary school transition year students (15 – 16 years) who were actively exploring future career options. This would be beneficial by preparing Ireland's future workforce with vital skills for, not just in ICT jobs, but more widely as a basic core competence in the future.

Realising that this knowledge would be required for both current and future workforce, Jamie agreed with city department managers that the programme would be targeted at both public sector staff and secondary school students.

While the Targeted Project would be focused on local authorities and schools within the Dublin region, the aim was to create a programme that could be scaled nationally, and even globally.

DCC and CONNECT also partnered with Smart Docklands and Irish IoT company Wia [Exhibit 6] to support the design and delivery of the programme. Smart Docklands had a strong understanding of the key challenges facing the Dockland areas and a network of relationships across the community, including secondary schools, which would support the programme delivery. Wia, a leading producer of IoT technology, provided a low-cost sensor kit to allow people with minimal coding knowledge to 'plug and play' with IoT.

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[2] A targeted project is an academic-industry collaborative project funded by SFI via the SFI research centre (CONNECT) and to which the industry partner is expected to make an intellectual and financial contribution.

Academy of the Near Future: Was it worth pursuing?

Earlier in the year, Jamie and the Smart Dublin team [Exhibit 7] had attended a 'makers' workshop facilitated by Irish company MakerMeet [Exhibit 8]. The goal was to teach technical concepts such as coding logic through 'play and doing'. Jamie found this approach engaging and effective. Having seen how easy the Wia IoT Platform and Sensor Kit was to use, he thought that this could be a great way to teach people about IoT.

Jamie's team agreed to run an initial 16 participant workshop with the broader Smart Dublin team and a few staff from local authorities across the Dublin region. They wanted to understand the potential value of the programme and to begin exploring the best delivery methods. To Jamie, this group was a 'trusted audience' – they knew the target audience well, would be confident to provide honest feedback, and allowed the project team to test out their first draft without any major reputational risk if it all went horribly wrong.

The two-hour workshop was run at the Dogpatch Labs Ideation Space [Exhibit 9] in the Dublin Docklands and was facilitated by Conal Laverty, the CEO and Founder of Wia. The purpose of this first workshop was to test whether participants saw value in the programme, to get feedback on the workshop style and content, and to understand how it could be improved to provide more value for local government staff [Exhibit 10].

During the workshop, participants were given an overview of a smart city, IoT and different connectivity options. Participants were asked to brainstorm city challenges that they had experienced or were working on in their current roles. Their challenges included flooding, noise control, pollution, congestion, energy consumption and waste [Exhibit 11].

Participants were then introduced to the Wia Cloud Platform and Dot One Sensor Kit [Exhibit 12]. These kits were equipped with the Wia Dot One Maker Board and a range of different sensors including; moisture, temperature/CO2/humidity, particulate matter, PIR (motion), noise and ultrasonic (distance). In pairs, participants were asked to choose a city challenge and explore how they could use the IoT sensors to provide information to help address the challenge they had chosen. Participants were given 30 minutes to connect their sensor(s) using the Dot One to the Wia Cloud, create a data feed, and to prepare a 90-second pitch which detailed how they proposed to use the sensor(s) to address the city challenge [Exhibit 13].

The final part of the workshop was a demonstration of how an IoT gully sensor was being piloted in the Dublin Docklands to help predict and reduce surface level flooding. It demonstrated that the sensor, when submerged in water (as would happen when a gully was blocked), sent a notification to a dashboard to alert the appropriate team in the Council that one of their gullies was blocked and now flooding.

Following the formal workshop, there was a 30-minute evaluation and feedback session. Participants filled in an evaluation form and then a facilitated discussion about their perspective on the workshop highlighting what worked well and what could be improved.

Jamie and the team found the pilot workshop and feedback session an incredibly valuable experience. The overall sense from participants was that they saw real value in the programme – with all scoring either 4 or 5 out of 5 as to whether they would recommend the session to others. General comments from the workshop participants included: "very educational, informative and practical", "very useful exercise to understand how IoT can be used to measure issues in a city location", "It was great to learn about the architecture and potential of IoT. Ideation exercise was great as a team building piece".

Participants also felt that the programme would provide benefit to not just local authority staff and secondary school children but also to a wider, more general audience including community groups and those looking to retrain or upskill. While the overall feedback indicated that there was value in teaching these concepts in an interactive way, the participants and project team also highlighted aspects of the session that could be improved.

Setting the Scene

The first section of the workshop covered the basic theoretical concepts. Participants felt this section was too brief and they wanted a better explanation of the key terms 'smart city', 'IoT' and 'connectivity'. It was also highlighted that these needed to be explained in the city context rather than just as isolated technical elements. Participants also felt that the demonstration of the gully monitoring sensor, which happened at the very end, should have been presented at the beginning as a way to bring to life the theoretical concepts participants were about to learn. The more visual aids to support the explanation, the better!

Building the sensor network

Participants reported that they loved being able to actually build their own sensor network – "very rewarding to build a sensor network myself", "really enjoyed the hands-on experience" and "great to see what's behind the technology". The participants enjoyed working in pairs, particularly those who had the least experience with this type of equipment. The initial demo of how to connect the sensor was too rushed and participants feedback that a step-by-step instruction guide in the kit or on the screen would have helped them a lot. As a result of the loose instructions some of the groups were not able to get to the stage of seeing data received on the dashboard.

Creating a connection from the classroom to the city

One of the challenges was how to create a connection for the participants between the learning topic and the challenges they were working on in their professional roles. Participants presented their ideas through drawing their concept on a whiteboard. While this was effective in helping them explain how they would use the sensor, participants commented that it would be great to be able to actually set this up in a real life setting following the workshop rather than simply a scenario on a whiteboard.

Beyond the workshop

There were a lot of questions during the session, and also on the feedback forms, asking 'where can I learn about other projects that use IoT?', 'where would I buy a sensor?', 'how do I know what connectivity was available and which one should I use?'. The challenge here was how to structure the programme in a way that it provides participants with all the information they require, without cramming the session so much that participants feel overwhelmed and lost.

While the pilot workshop helped to cement Jamie's view that there was value in developing the programme further, it had also surfaced a lot of questions about the design and delivery of the programme. How should he structure the programme in a way that participants can access all the relevant information? How could he bring technical concepts to life so it's not just technical jargon? How would it be scalable? How should he design the programme so participants take the learning beyond the classroom?

Applying Lessons Beyond the Classroom!

Jamie's motivation for creating the programme was to increase the utilisation of IoT to address city challenges. To make the programme a success, Jamie and his team not only had to think about the most

effective way to structure the programme in order to suit the two distinct audiences (students and city staff) in a way that was scalable, but also how to do it in a way that would encourage participants to take the learning beyond the classroom to solve city challenges. A number of questions emerged, such as: Does it need to be a physical, in-person workshop? Could it just be delivered online as self-directed learning? Should there be more than one module?

Designing for action

When trying to understand the best way to design the programme for the two target groups, Jamie discovered the concepts of *pedagogy* (the art and science of helping kids learn) and *andragogy* (the art and science of helping adults learn). These concepts helped him to explore what would motivate the two audience groups to participate in educational programmes.

For adults, learning was predominantly a self-initiated process where they had a choice to participate and would only do so if they saw that it would provide value to their ability to do their job more effectively or if it would assist them to progress (Pappas, 2015). This was echoed by one of the pilot workshop participants (an engineer from Dublin City Council) who said that to participate in a course he needed to "see a direct connection between what was being taught and how it will benefit him in his work" (Dublin City Council Engineer, personal communication, 26 March, 2020).

For children, their participation in a programme was generally determined by their teacher, but their motivation to engage would be driven by a desire to master new skills and a focus on an interesting topic to which they could relate (Pappas, 2015). From this we can understand that the programme, as echoed by the participants in the pilot workshop, needed to enable participants to connect the theory with scenarios that they were familiar with in their professional or personal life.

When looking at how to structure the programme there were two elements to consider: how to create a programme that best enabled participants to learn, understand and take action beyond the programme and, how to make a programme that was scalable.

Jamie researched different learning theories to understand the best way to teach both children and adults that would encourage the participants to turn the theory into action. He discovered Experiential Learning Theory (ELT), a leading educational concept developed in the 1980s by David Kolb (Figure 1) that was recommended for both children and adults and was focused on helping participants put theory into action (McLeod, 2017). In its simplest form it promoted the idea that participants "'learn by doing' and by reflecting on the experience" (Boston University, n.d.). This theory promoted the idea of a four-phase cyclical learning process where the participants learn, reflect and take action.
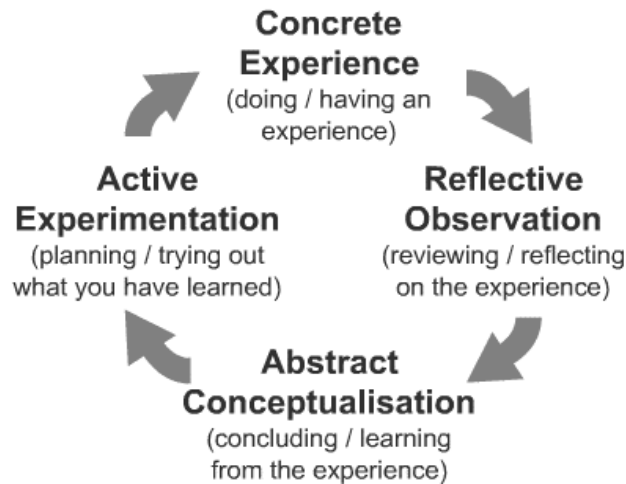
Figure 1: Kolb's Experiential Learning Cycle (McLeod, 2017)

ELT aligned with Jamie's objective to encourage participants to take the learning beyond the classroom. As the programme aimed to get participants in a position where they were comfortable to design and use an IoT system to address a city challenge, Jamie wondered if the Smart Docklands team should then have a workshop similar to the pilot as part of the programme?

The four-phase process also suggested that the structure of a programme should include multiple touch points – what would the other 'touchpoints' look like? Would this all be in-person or could it include online learning materials?

Workshops would require a facilitator. Would they need to be approved facilitators that were paid, or could we use volunteers across the country? The benefit of approved facilitators was the ability to control the programme delivery to ensure a certain standard. However, this could be very costly and logistically challenging. Would it be better to use a volunteer model similar to that of CoderDojo[3] to allow the programme to scale more easily? CONNECT is a national research centre with team members in ten Higher Education Institutes around Ireland, could training be brought inhouse to provide a more scalable solution?

While the ELT theory aligns with the objective of translating learning to action, the programme structure it promotes could be challenging when one looks at the second objective of how to make the programme scalable across Ireland. Should Jamie look at self-directed learning processes where the learning material was provided to participants who read through it and taught themselves? Jamie thought this could be a much easier way to make a programme scalable as his team could have materials online, reducing any logistical barriers to access and delivery of the programme. But could they be confident that participants would engage properly and be able to move the knowledge beyond the classroom?

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[3] CoderDojo is a true global movement and phenomenon. Volunteers all around the world help young people build a positive future through coding and community. CoderDojo is supported by organisations and philanthropists who share our vision of a world where every child has the opportunity to learn to code and be creative in a safe and social environment. https://coderdojo.com/about/

Decision Summary

Having secured funding for a pilot project with CONNECT, Jamie and his project team now needed to decide on the best way to design and deliver the "Academy of the Near Future" programme. They needed to select a structure that would provide participants with a strong foundational knowledge of IoT so participants would feel confident to explore and utilise IoT technology to address the city challenges they faced. The structure would also need to allow the programme to be scalable and accessible whilst utilising best practice teaching methods for both secondary school students and professionals. As Jamie walked along Dublin's River Liffey to the Smart Docklands office, he pondered which of the following options would best result in city officials integrating IoT technologies such as the smart gully sensor into the cities infrastructure?

- **A self-directed online lesson** would allow the programme to be easily scaled from Dublin across Ireland and potentially even globally. Having free materials online would remove any logistical barriers to participation as participants could access the resources at their own convenience. This would be a very cost-effective option. A limitation of this option was that participants would not get to physically interact with the technology themselves which could reduce their engagement with the course content. It is also relying on participants to drive the learning themselves, while this might be suitable for local authority staff, this could be a barrier for participation for secondary school students. With only one lesson there was also a risk that participants may become overwhelmed with information as they will not have the time to reflect and apply the learnings before progressing to the next concept. Translating learning into action could also become a problem if participants are not able to digest all the information required to utilise the skills in their own role.

- **Self-directed online learning modules** would allow participants from all over Ireland across the two targeted audiences to easily access the learning materials. The modular approach would mean that participants are able to learn, reflect and apply learnings between each lesson rather than trying to take in everything at once. Having the course only online may however restrict participants' ability to fully engage with the content as they aren't able to physically build their own sensor network without purchasing a kit themselves.

- **A one-off facilitated face-to-face learning session** would allow participants to understand the key concepts using the 'learn by doing' approach as they built their own sensor network to address a chosen problem. Participants would also get to trial technology without any financial barriers. The in-person workshops would also allow for collaboration between participants and shared learning as they see the different type of challenges and solutions used by their peers. With only one workshop it could be difficult to fit in all of the desired content without overwhelming the participants. This option would also require a facilitator to run each session which would impact on the scalability, cost and potentially the accessibility of the programme. A one-off touch point might also not be enough to sustain longer term engagement with participants who were learning about IoT for the first time.

- **A combination of online and face-to-face learning approaches** would allow participants to enjoy the benefits of both the in-person workshop as well as accessing additional learning materials online in their own time. By having supplementary resources online there would be less pressure to fit all the information into one workshop. This approach could allow participants more time to explore the sensors and ensured they are were not overwhelmed. It also enabled participants the reflection time between learning. However, this option could be costly as it would

require the purchasing of the sensor kits, development of online material as well as a facilitator to deliver the programme.

About the Authors

Julia Hamilton is the Team Leader of Digital Innovation at Wellington City Council (New Zealand). She is responsible for exploring and identifying opportunities to develop and deliver innovative digital solutions for Wellington City. She previously held the position of Innovation and Engagement Lead at Smart Docklands - a unique smart city testbed in the heart of Dublin's Docklands. Julia led the Community Engagement Programme, working closely with a diverse range of local stakeholder groups including resident groups and schools to identify challenges which can be addressed through new smart city technology and applications. With a background in Community Development and Emergency Management, Julia has a passion for exploring how we can harness the power of innovation, collaboration and technology to better understand and address complex societal problems. She is a strong advocate for engaging citizens to help identify and address city challenges through citizen science and co-design. Through her work at Smart Docklands and Wellington City Council, Julia has extensive experience leading public engagement activities and innovative projects with a broad range of stakeholders from across government, industry, academia and citizens. Julia holds a Bachelor of Arts in Politics and Public Policy, and a Master of Commerce in Public Policy from Victoria University of Wellington, New Zealand.

Matthew Mullarkey (Ph.D.) is the Director of the Doctor of Business Administration (DBA) Program for the USF Muma College of Business and an Instructor in the School of Information Systems and Management (SISM). Mullarkey is a 2019-2020 recipient of the Fulbright Scholar Award, 2018 recipient of the USF Faculty Externship Award, 2017 recipient of the USF Muma College of Business Outstanding Faculty Community Engagement Award, and 2015-2016 ISDS Undergraduate Teacher of the Year Award. Mullarkey's areas of research interest include design science research and action research in the evaluation and creation of information systems, smart cities, IoT, healthcare, social networking, and data science. Mullarkey teaches using case-based discussions that engage Doctoral, MBA and MIS undergraduates in complex business decisions that typically involve a technology component. His service includes active engagement as an instructor, coach and mentor with start-up companies involved with USF Connect, Tampa Bay WAvE, Florida-Israel Business Accelerator, and the Greater Tampa Chamber of Commerce Start-up Scholars. Mullarkey works to integrate his business experience with the needs of the students, faculty and administration of the USF Muma College of Business in ways that contribute to student education and preparation for jobs, increases partnering with the Tampa Bay business community, and informs research with impact.

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Acknowledgements

Exhibit 1: Low Cost Gully Sensors

As part of Small Business Innovation Research (SBIR) Programme, Dublin City Council and Enterprise Ireland launched the Gully Monitoring Challenge in 2017 to seek innovative solutions that could improve local authority responses to flooding. The aim was to use technology to maximise the use of limited resources by monitoring gullies, especially in high risk areas.

These sensors are now being deployed in targeted areas across the Docklands. The sensors monitor whether a gully is clear or if it is blocked. Using a low powered wide area network they send information back to the Council to shows the status of the gully e.g. clear or blocked on a dashboard. The detection of a blocked gully will trigger an alert to the Council's Gully Monitoring team allowing them to deploy resources to clear the gully. Having a view all of the gullies on one dashboard, the Council can better manage operations through real time data and predictive analytics.

Project Outcomes

- Real-time information allows local authorities to prioritise resource deployment to the areas that need it most.
- More efficient responses to blocked gullies will reduce the number of flooding instances and flow on effects such as road closures.
- Through collecting information about when drains are blocked the Council can use predictive analytics creating a more efficient pre-emptive clearing schedule
- The benefits of developing solutions through a pre-commercial procurement process, such as the SBIR programme, has allowed for front-line local authority staff to co-create solutions to this challenge.

Source: https://smartdocklands.ie/project/low-cost-gully-monitoring-sensors/

Exhibit 2: CONNECT Research Centre

CONNECT is the world leading Science Foundation Ireland Research Centre for Future Networks and Communications. CONNECT is funded under the Science Foundation Ireland Research Centres programme, which has established a network of SFI Research Centres focusing on key research areas in Ireland. The centre is co-funded under the European Regional Development Fund.

CONNECT brings together world-class expertise from ten Irish academic institutes to create a one-stop-shop for telecommunications research, development and innovation. We engage with over 35 companies including large multinationals, SMEs and start-ups.

Our Research focuses on different aspects of future networks and communications. We want to design open communication systems that enable multiple services providers to share network resources as they compete to satisfy the demands of a diverse set of end users.

CONNECT has a dedicated Education and Public Engagement Team who are focused on increasing public awareness of networks and communications research and its benefits to Irish society, and also increasing public understanding of key technical concepts relating to future networks and communications.

CONNECT is one of the key partners of the Academy of the Near Future Education Programme. They bring technical excellence in the areas of both education methodologies and connectivity which was pivotal in the development of the Academy of the Near Future Programme.

Source: https://connectcentre.ie/

Exhibit 3: Enable Research Programme

Connecting communities with smart urban environments through the Internet of Things. In collaboration with industry partners and via citizen engagement, ENABLE is addressing the challenges that currently limit the potential benefits of IoT for communities. This involves a focus on enabling smarter buildings, more efficient transportation/ mobility, better handling of environmental issues, stronger data privacy, and enhanced cyber and infrastructure security.

ENABLE has three research strands supported by a cross-cutting theme of Citizen Engagement, reflecting ENABLE's human-centric approach of engaging people in the co-design of technology solutions that will affect their daily lives.

ENABLE has access to a range of test-beds that allow our technology to be deployed outside the laboratory. These test-beds allow us to combine, assess and evaluate results from our three research strands. This is vital to ENABLE's mission of closing the sense-analyse-actuate loop and measuring impact on real people.

ENABLE , which is co-funded by the European Regional Development Fund, is led by the CONNECT Centre in partnership with two other SFI centres: the INSIGHT Centre for data analytics, and the LERO software research centre.
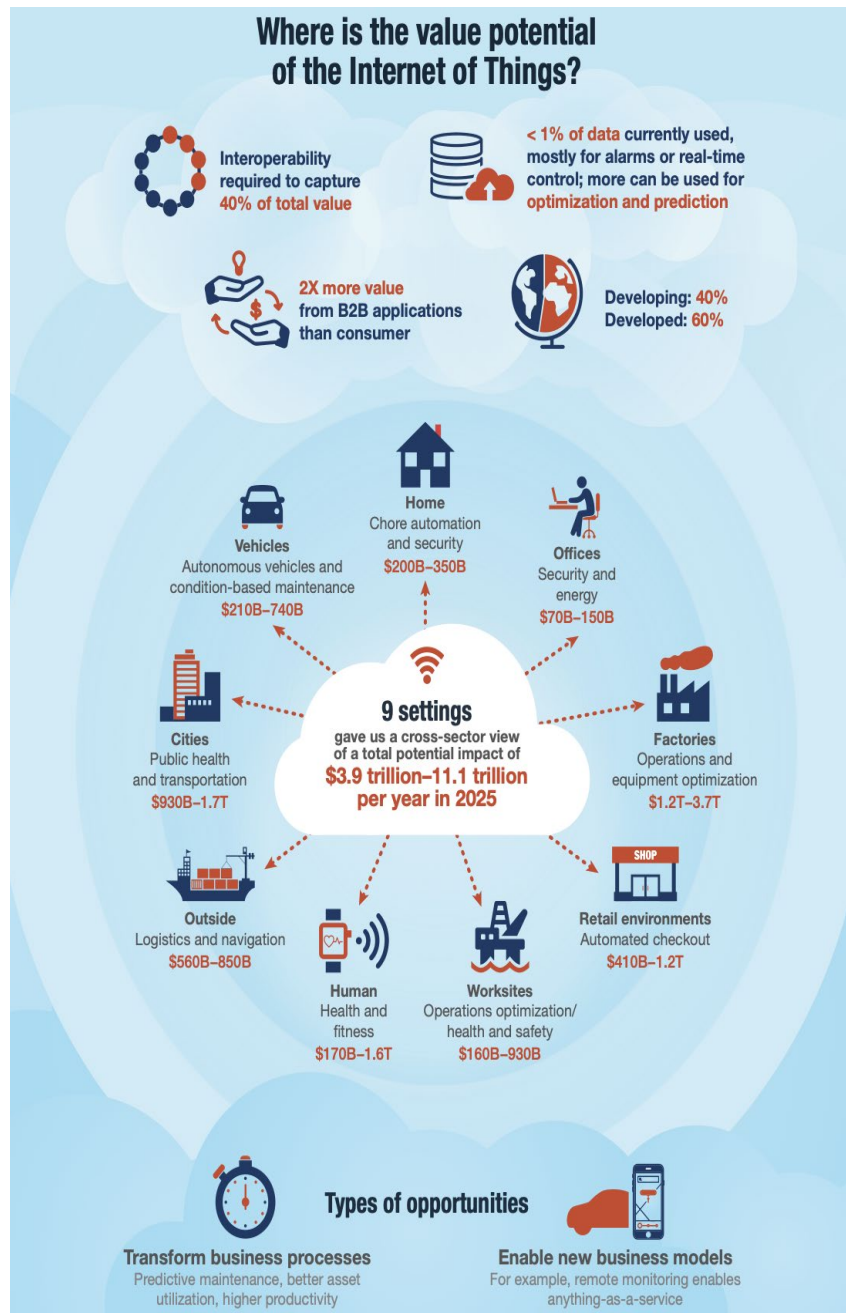
Source: https://www.enable-research.ie/

Exhibit 4: The Internet of Things
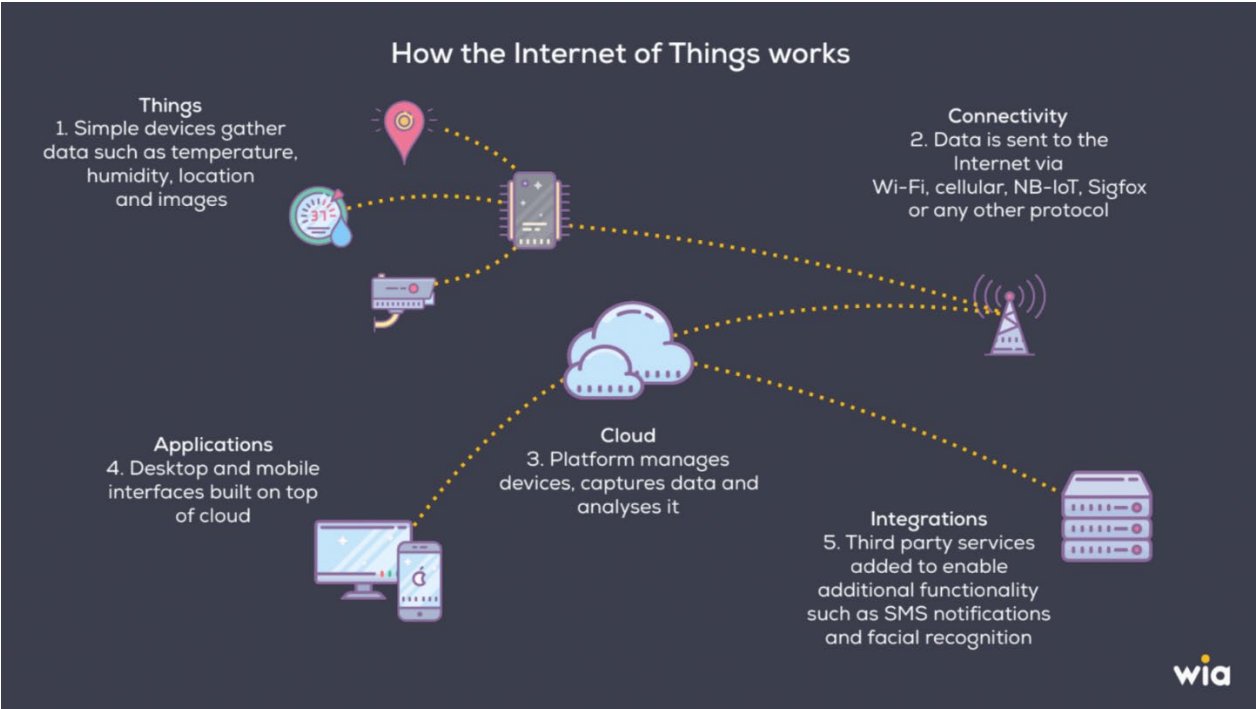
Source: Wia Technology Ltd. *Personal Communication,* (January, 2020).

Exhibit 5: Internet of Things Potential Value

Source: McKinsey Global Institute (2015).

Exhibit 6: Wia Technologies Ltd

Wia is a leader in the Internet of Things (IoT) industry, building the next generation of smart, connected solutions for companies across a range of different verticals. They provide an end-to-end innovation platform that allows organisations to find, develop, test, and deploy Internet of Things solutions.

Wia works with teams and organisations at any point along their journey from pre-concept development through to scaling and deploying their solution. By bringing all the elements of IoT together - Hardware, Software, and Connectivity - Wia helps businesses overcome the barriers holding them back from executing successful projects with connected devices.

Wia's technology is low cost and designed to allow people to 'plug and play' and requires minimal prior coding knowledge to use. Wia provided technical expertise as well as supply hardware and software to the programme.

Source: https://www.wia.io

Exhibit 7: Smart Dublin

Smart Dublin, an initiative of the four Dublin Local Authorities, brings together technology providers, academia and citizens to transform public services and enhance quality of life. Our goal is to future-proof Dublin by trialling and scaling innovative solutions to a wide range of local challenges. From tackling the climate crisis to bridging the digital divide, we believe that through collaboration and innovation we can build a better, more resilient Dublin. We fast-track innovation projects through our Smart Districts.

Smart Projects

Smart Dublin innovation projects take place across six key themes.

- Smart Environment: How can technology help build a greener, more sustainable Dublin?
- Smart People: How can local government use technology to better engage with Dubliners?
- Smart Mobility: How can we better manage pedestrian, cycle and vehicle flows and reduce congestion?
- Smart Economy: How can we use smart technologies to improve liveability and competitiveness?
- Smart Government: How can we use technology and data to deliver better services and make better decisions?
- Smart Living: How can technologies help bring communities together and improve citizen well-being?

Governance

Smart Dublin is a collaboration of Dublin City Council, Dún Laoghaire-Rathdown , Fingal County Council and South Dublin County Council.

The regional project team is co-funded by the four Local Authorities and governed by a Steering Committee.

Within Dublin City Council, a dedicated Smart City team sits within the Chief Executives Department. In Dún Laoghaire-Rathdown, Fingal County Council and South Dublin County Council smart projects are embedded in the I.T Departments.

Source: www.smartdublin.ie

Exhibit 8: MakerMeet

With an emphasis on maker-led, project-based learning, **MakerMeetIE** aims to help teachers bring MakerSpaces into their classrooms and help students explore the fun of working and learning together. We use S.T.E.A.M. (Science, Technology, Engineering, Art and Maths) to work together to make cool stuff – what could be more fun? Problem solving combined with creativity are at the heart of this hands-on, collaborative learning process.

Since 2017 a MakerMeet has been held before the ICT in Education conference in Tipperary. MakerMeetIE has evolved to extend the reach beyond this once a year event to encourage more teachers across the country to engage with the Maker movement to bring S.T.E.A.M. to classrooms nationwide.

MakerMeet facilitate a wide range of interactive workshops on topics including; coding, robotics, cardboard engineering and stop-motion animation.

Source: https://makermeet.ie

Exhibit 9: Dogpatch Labs

Dogpatch Labs is a startup hub located in the CHQ building, in the heart of the Silicon Docks, supporting the startup ecosystem through incubation and acceleration programmes, educational events and a tech community of over 500 members from 100+ startups. In 2019 it was listed as Crunchbase's "top 10 incubators around the world you need to know".

It is a member of a global network of 50 startup hubs supported by Google For Startups and winner of its Global Citizenship Award in 2017 and its Global Diversity & Inclusion Award in 2018.Visitors have included The Duke & Duchess of Sussex[6] and also The King & Queen of the Netherlands in recognition of Dogpatch's mission to accelerate the development of Ireland's entrepreneurial ecosystem.[8]

Partners include Unilever, Google For Startups, Alltech, ESB, Ulster Bank, Pivotal, CHQ, and Hannover Re.Alumni include Irish tech unicorn Intercom and provides the global headquarters for CoderDojo, the volunteer-led movement of free computer programming clubs. Dogpatch actively supports other social technology initiatives such as ChangeX, HackAccess, PyLadies, Social Innovation Fund and others.

Source: https://dogpatchlabs.com/

Exhibit 10: Pilot Workshop Agenda

IoT Education Pilot Workshop - Smart Dublin Team

Date: Thursday 30, January - 10am - 12:30pm, Dogpatch Labs Ideation Space
**Facilitator:** Conall Laverty

Objectives:
- Understand practical applications of IoT to city challenges
- Solve a city challenge using a set of IoT sensors
- Provide feedback on workshop to inform programme development

Time	Activity
10:05am - 10:10am [5 mins]	**Programme Overview**
10:10am - 10:20am [10 mins]	**Ice Breaker**
10:20am-10.30am [10 mins]	**Ideation of City Challenges**
10:30am - 10:40am [10 mins]	**Introduction to IoT & Connectivity**
10:40m - 10:55am [15 mins]	**Setting up your Dot One Maker Board**
10:55am - 11:15am [20 mins]	**Setting up a sensor to solve a city challenge**
11:15am - 11:35am [20 mins]	**Visualising the data**
11:35am - 11:55am [20 mins]	**Sharing outcomes**
11:55am - 12:05pm [10 mins]	**Wrap-up**
12:05pm - 12:30pm [25 mins]	**Feedback**

Source: Smart Docklands, *Personal Communication,* (January 2020)

Exhibit 11: Pilot Workshop – Participants City Challenges

The Post-Its are the different challenges that participants highlighted as affecting them personally or which they are trying to address in their work.


Source: Smart Docklands, *Personal Communication,* (January 2020)

Exhibit 12: Wia Dot One Sensors & Cloud Platform

The Wia Dot One Kit is designed for 'plug and play' allowing participants to easily be able to connect a sensor network together.
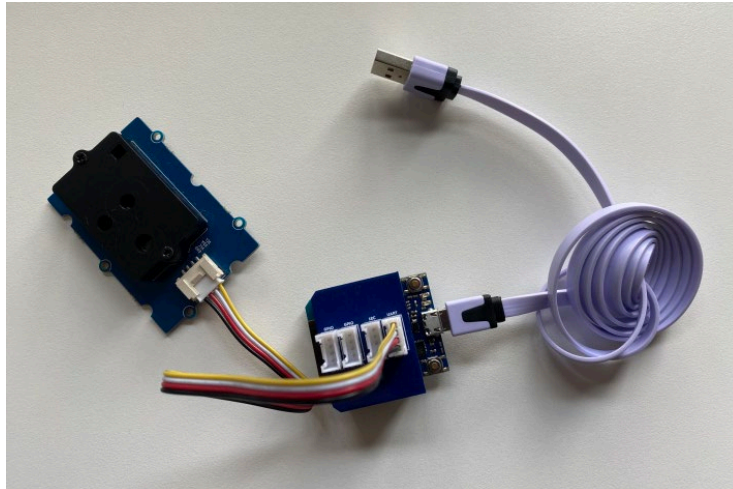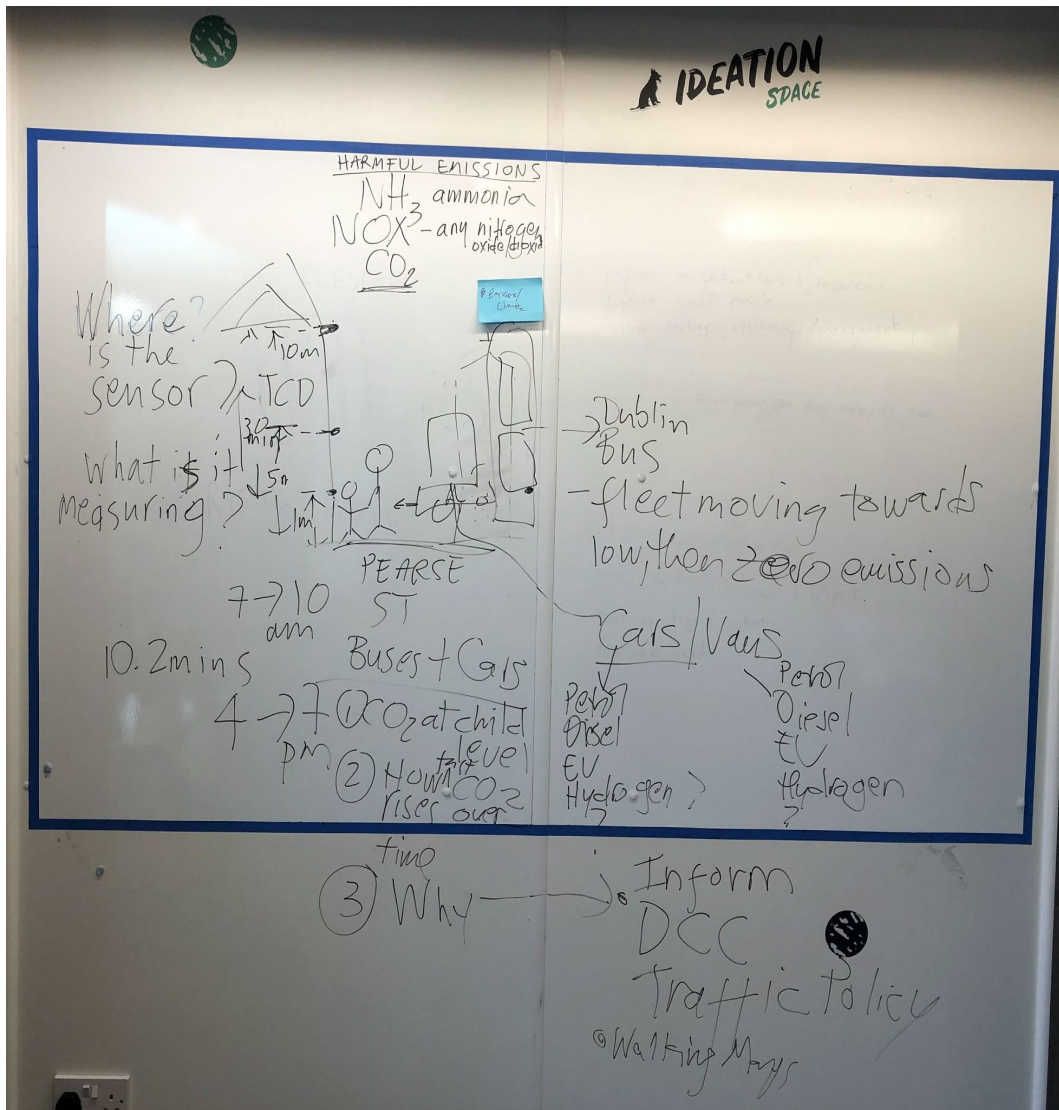

The Wia Cloud uses 'blocks' to make coding the sensors easy for participants and meaning that barriers to engaging with IoT are significantly lowered.
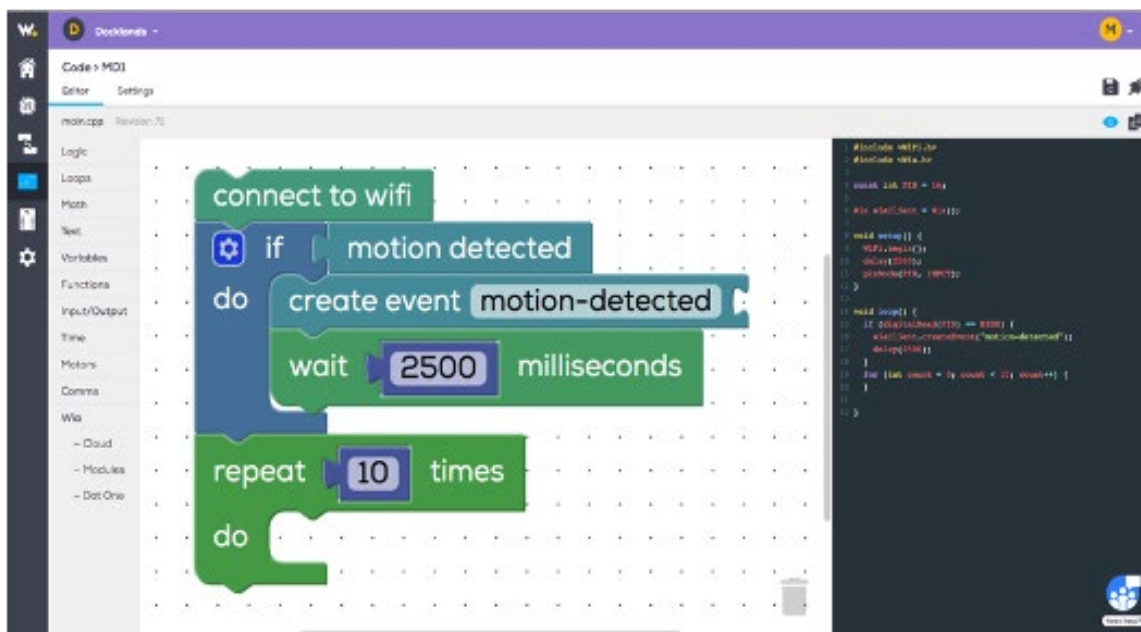
Source: Wia, *Personal Communication,* (January, 2020)

Exhibit 13: IoT Solution Pitch – addressing air quality issues

This solution looked to address the issue of poor air quality on Pearse Street Dublin. The participants proposed that by having particulate matter sensors installed on the street they would be able to provide factual evidence of the extent of the issue with the quality of the air in the area. This information could then be passed onto Dublin City Council who could look at contributing factors such as too many buses using diesel and review their transport policies and goals.

Source: Smart Docklands, *Personal Communication,* (January, 2020)