From VizBlocks to the Data-Driven Actor

Reimagining an open-ended data physicalisation prototype with a creative business

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From VizBlocks to the Data-Driven Actor: Reimagining an open-ended data physicalisation prototype with a creative business

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Figure 1: (left) The original VizBlocks prototype and (right) the Data-Driven Actor motorised emoji

ABSTRACT

In this case study, we document the process of engaging in an initially unplanned and informal knowledge exchange activity between academic researchers and a local performing arts company. This knowledge exchange activity quickly became a fruitful collaboration during which an academic design research prototype was reimagined as a wholly new product to expand the offering of a creative business. We document the factors that led to the success of this collaboration, reflecting on both features of the collaboration itself and how the design of the initial research prototype configured its repurposing. In terms of the latter, we consider how the original prototype's ambiguity, open-endedness, customisability and flexible assembly afforded its reimagining. Through the case study, we demonstrate that there is much to be gained from facilitating access to research prototypes for small and medium enterprises and supporting them in appropriating these toward their own goals.

CCS CONCEPTS

• **B7; Human-centered computing**; • **Interaction design**;

KEYWORDS

Design research, research through design, data physicalisation, data literacy, industry collaboration

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1 INTRODUCTION

Design research often involves the development and testing of physical prototypes to further our understanding of a given domain. However, these prototypes are constrained in how they are used and are often employed primarily for empirical work. How might

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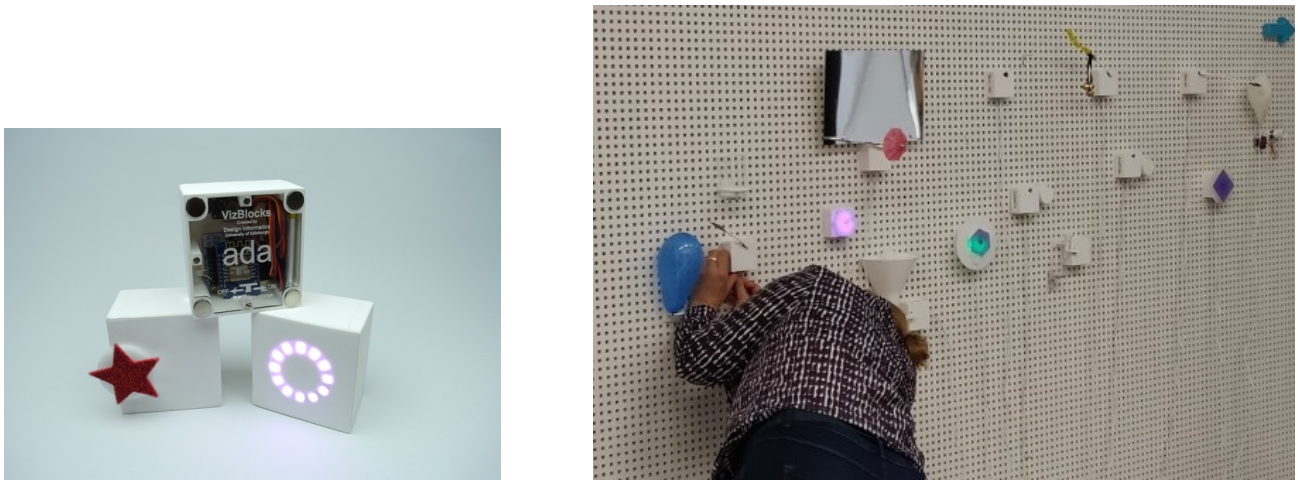

Figure 2: (left) individual VizBlocks blocks, clockwise, including the back of a modular block showcasing its internal electronics, an LED ring block, and a servo-motor block with a craft material star attached. (Right) VizBlocks physicalisations mounted on a paneled wall in the design studio.

the prototypes we create as academics be enabled to take on a life of their own beyond just planned research activities? What might the potential value of such design prototypes be for inspiring and supporting the work of local businesses or communities? Moreover, what design features of a physical prototype, and configurations of collaboration are needed to enable this to happen?

To reflect on these questions, we present a case study where a local creative business reimagined an existing academic design research prototype for a new, applied context. Specifically, we describe the journey of appropriating VizBlocks [18], an open-ended data physicalization prototype, into the Data-Driven Actor [19], a motorised emoji for playfully interacting with data, designed for use in educational workshops with children and young people. This reimagining was the product of an informal collaboration between design academics and Civic Digits, a creative theatre company who were seeking to integrate new digital technologies into their performances and educational workshops. This informal collaboration, which was initially aimed at supporting knowledge exchange and had no set agenda, ultimately supported Civic Digits in successfully trialing a new business model as well as upskilling in the domain of physical computing, thus opening up new directions for their creative practice and business. As a result of the work, the Data-Driven Actor has reached over 2,600 pupils across Scotland and England so far, bolstering the impact of the initial academic research.

In this case study, we describe how the process of reimagining our initial prototype with Civic Digits unfolded; we provide an account of the original VizBlocks prototype, the informal collaborative process and the resultant Data-Driven Actor kit, highlighting its impact. We reflect on what led to the success of this collaboration, considering how the openness of both parties engendered a cooperative curiosity that supported imaginative exploration of how the existing design object might be made useful for a new design brief. Moreover, we reflect on how the design of the initial VizBlocks prototype itself afforded its appropriation. Specifically, we demonstrate how its open-endedness, customizability, and ambiguity enabled it to be seen as a construction toolkit [3]. We also show how the feature of flexible assembly embedded in VizBlocks helped configure a compelling structure for educational workshops with 12-to-14-year old school pupils.

While there is a wealth of work within HCI that deals with designing systems with and for communities with the intention of the design living on beyond research (e.g., [2, 9]), designing technology that supports end-user creativity and improvisation (e.g., [5–7]) as well as DIY data physicalisation tools (e.g., [7, 17]), our case study instead provides an exemplar of the process of reimagining and handing over an existing design to new stakeholders and towards a different purpose. By reflecting on this process, we hope to demonstrate that there is much to be gained from facilitating access to research prototypes for small and medium enterprises and supporting them in appropriating these toward their own goals.

2 THE VIZBLOCKS SYSTEM

VizBlocks is a dynamic data visualisation kit which offers new ways of physically representing data using modular blocks. With a range of materials, mechanisms and tools, VizBlocks can be used to translate data into playful and engaging physical data displays, with little need for existing technical/coding knowledge.

At the start, VizBlocks was about making it easy to physicalise data, and exploring accessible ways of creating data physicalisations that made use of space and matter. The block-based design was inspired by the acoustic paneling of our design studio - a grid of small square holes that invited things to be made that would fit them (see Figure 2, right). We developed ideas for modular elements to plug into the paneled wall, that could be actuated by different electronic components to form dynamic and interactive data physicalisations. This initial wall-based design was intended as a way to attach visualisations to walls, for a semi-permanent but modifiable intervention, somewhere between data display and sculpture.

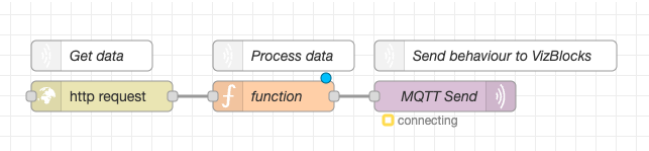

Figure 3: The NodeRED interface for VizBlocks

From this we started thinking about what a basic unit of physicalisation would be in this space: something that could be connected into the grid, but that would respond to data, and allow people to create their own ideas and meanings for it. For example, we explored ways to attach a servo motor to a block, that could take a certain angle, followed by some exploration of what to attach to it (see Figure 2, left). We were interested in how physical materials could be brought in to affect the scale and reach of the servos, for example, bells to make sound, strings to connect over distances and other standard craft and design materials that could be connected in support of creative, reactive, engaging physicalisations. In this way we aimed to design a dynamic and reconfigurable system that would offer low cost, accessible and situated engagement for novices or non-specialists with tangible data. Drawing from design resources and features in HCI, these modular components were kept as simple white blocks to serve as a blank canvas. We aimed to design for ambiguity [8], open-endedness [7] and unfinishedness [12] of the individual designed blocks to enable users to adopt a bricolage practice [16] by adding a series of materials and making different associations between data, material and meaning.

Alongside designing the modular blocks, we were interested in how to make them easy to control and to develop a simple, visually programmable system to incorporate different online data streams as inputs combined with the blocks as outputs (see Figure 3.). This led us to use Node-RED [13] as a way to shape dataflows, with a range of initial data streams as examples, but also creating an Arduino [1] library with a range of behaviours that people could make use of to animate each block. Rather than simply telling a motor on a block to move to a specific position, we envisioned more engaging behaviors like 'wiggle' or 'breathe' - a motion that unfolds over time. This was an attempt to take away some of the hard work of programming temporal behaviours and starting to come up with a language that was appropriate to this kind of physicalisation. In this way we hoped to minimize a user's need to understand much programming and to enable people to use the blocks with little technical support.

In sum, the main purpose of VizBlocks in its first inception was to offer non-specialists an accessible and simple way to represent, translate and interpret online data streams into creative and material interactions. Through initial concept prototypes (Figure 2) and focus groups we investigated how such a potential system could be utilised in different contexts, e.g., for IoT management, for public engagement at festivals and by digital educators to explore data literacy and pedagogy. This led to developing a standalone mobile unit version for VizBlocks and starting to explore how to develop workshops around it. This is the point where Civic Digits joined and started appropriating the creative possibilities into their practice.

3 DEVELOPING THE DATA-DRIVEN ACTOR

3.1 Introduction to the collaboration

Civic Digits is a small creative theatre company comprising a group of freelancers, who work to engage children and young people with Science, Technology, Engineering and Mathematics (STEM) subjects, and who are interested in innovatively applying digital technology in the performing arts. Civic Digits comprises one full-time staff member (founder and artistic director Clare Duffy, referred to as CD), and approximately five other part-time members who contribute to Civic Digits' activities to varying degrees, depending on the projects being run at a particular point in time.

The collaboration with Civic Digits emerged from word-of-mouth connections within our networks. In particular, an academic colleague who was familiar with the work of Civic Digits, introduced CD to our university department and arranged for CD to visit our design studio.

At the time, Civic Digits was developing an accredited course for 12–14-year-old school pupils, to enable them to think critically about how data impacts their lives, and to help them to understand and experiment with data in creative ways. The course was planned to include both theatre and interactive workshop elements, with the latter being intended for school classrooms.

As part of this development, Civic Digits were looking to incorporate digital technology in novel ways into their interactive workshop activities and to explore possible connections between data, materiality and performance that could make their engagement in schools even more relevant, interesting and exciting for school pupils. CD visited our design studio and was introduced to a range of research prototypes, including among others VizBlocks. While initially the idea of data physicalization and VizBlocks were not aligned with Civic Digits' vision for their workshops, they decided it would be worthwhile to explore the creative potential of the modular components that the school pupils could stick/attach different materials to, which could then be animated in some way. This was of interest to the academic researchers as a way to explore how VizBlocks might be used in practice, but also given our wider empirical interests in how creative practice might be used as a resource for digital fluency (e.g., in line with [4, 10, 11]). We thus proceeded to explore ideas together through an open-ended and initially informal collaboration.

After this initial introduction, a core team of approximately six people from Civic Digits and the university, who were interested in working together, became actively involved in the project and stayed active in the work throughout the collaboration. Other individuals from both Civic Digits and the university also contributed at various points in time (e.g., during ideation stages, or the deployment stages). The core team's backgrounds included expertise in theatre and the performing arts, interaction design, physical computing and app development. The academic researchers who were involved had particular interests and expertise in critical and creative approaches to data representation, as well as novel approaches to computing education.

3.2 Reimagining the prototype

After the introductory meeting, Civic Digits decided to develop a design concept based on VizBlocks for their planned educational

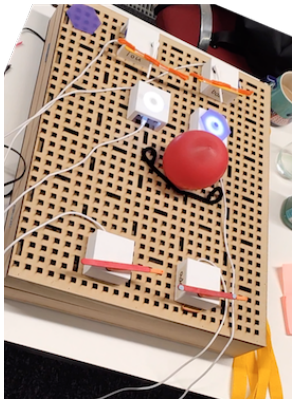

Figure 4: (left) our first attempt at reimagining VizBlocks as a motorized emoji; (right) a Data-Driven Actor kit customized and programmed by pupils

workshops. The design concept they brought forward was to use the VizBlocks modules to create a motorised emoji, which would be able to emote by responding to data that it received. The motorised emoji was envisioned to be customisable, such that the school pupils would be able to combine a set of actuator blocks into a face, and then personalise these with craft materials (see Figure 4). This could then be controlled using a student-facing mobile application so as to make various facial expressions based on the data received, for example smiling or frowning. The customisability of the blocks, through both controlling them and augmenting them with craft materials, was aimed to help the students engage with the technology but also to promote a feeling of agency over controlling the motorised emoji.

Two initial collaborative design sessions were held with four members of Civic Digits (the creative director, chief technology officer, producer, and a creative technologist) and three members of the academic research team (specializing in software engineering, interaction design and critical perspectives on digital technology) to decide what actuator blocks, control settings and craft materials could be best combined into a kit that could be brought into schools. Through experimentation, we decided that a simple way to create a face using the blocks available would be to include five blocks as a kit: two LED ring blocks representing eyes, two motor blocks representing eyebrows, and one motor block representing a mouth. These five blocks (two LED and three motor blocks) were ultimately assembled with magnets and a metal surface as mobile kits and together, and this kit of combined materials became known as the 'Data-Driven Actor'. We also experimented with how these actuator blocks might be programmed by the school pupils to represent a variety of emotions. For example, the LED rings embedded in the blocks were able to be programmed to change colour, brightness, and the number of illuminated LEDs – so a user might decide that sad eyes might be represented by illuminating only a few LEDs and colouring them blue, or that happy eyes might be represented by flashing orange LEDs. Likewise, the motor blocks were able to move in a way such that overlayed craft materials, for example a feather or popsicle stick, could mimic eyebrow and mouth shapes (see Figure 4). Finally, we decided that a variety of craft materials (e.g., paper, felt, feathers, semi-transparent acrylic overlays) that could be attached to the blocks by students should be provided to the students to encourage creativity.

3.3 Deciding on the data to drive the actor

The next question we faced was: what data could be used to control the Data-Driven Actor in a way that would be compelling to the school pupils? For the first iteration, two data streams were used to develop proof of concept applications. The first application used real-time facial expression data, by using a smartphone front camera to estimate a level of 'happiness' or 'sadness' in a person's facial expression as a basic take on emotion recognition, and then mapping this data to the behaviour of the Data-Driven Actor. For example, depending on the end-user programming, smiling into the smartphone camera might make the Data-Driven Actor smile, and in contrast, frowning into the smartphone camera might make the actuators on the Data-Driven Actor be positioned into a frown.

The second proof of concept application used historical weather datasets. This was to show how existing datasets could be used as an input to the Data-Driven Actor. For this functionality, historical weather data representing daily levels of rainfall was mapped to emotion and then represented via the expression of the Data-Driven Actor over time. The concept was planned to be extended at a later stage to enable a wider variety of datasets to be input by the students.

We wanted to make it as simple as possible for the students to configure and control the VizBlocks and data mapping. Node-RED provides a "low code" user interface, however this still requires some basic on-boarding and tuition. Consequently, we decided to make a simple web interface using Node-RED's uibuilder library [15] (see Figure 5). The interface has a dropdown selector at the top, which allows students to select the block they want to program. They can then set configurable parameters for that particular type of block (LED or motor). For LED blocks the interface enables setting the colour and number of lit LEDs, and for motor blocks, it enables setting the angle.

4 OUTCOMES

4.1 Pedagogical use

The overarching goal of Civic Digits' school workshops was to engage 12-14 year old pupils in viewing data as a creative material, i.e., something that can be explored, creatively engaged with and played with. To this end, Civic Digits incorporated the Data-Driven Actor kit that we designed together into the workshop as part of a larger set of tools and activities, including group discussions, crafting and theatre. Specifically, the Civic Digits workshops started with an icebreaker, where the students were asked to discuss their understanding of, experience with and feelings toward data. They were then introduced to the Data-Driven Actor, and asked to test out the facial expression feature - which mapped their own facial expressions (i.e., smiling and frowning) to the expression of the Data-Driven Actor – via a smartphone camera. Each group in the class was then provided with one facial feature of the Data-Driven Actor, such as a left eye, or a right eyebrow. Each group was then tasked with using craft materials to decorate and customise their given facial feature, and then to program the behaviour for that

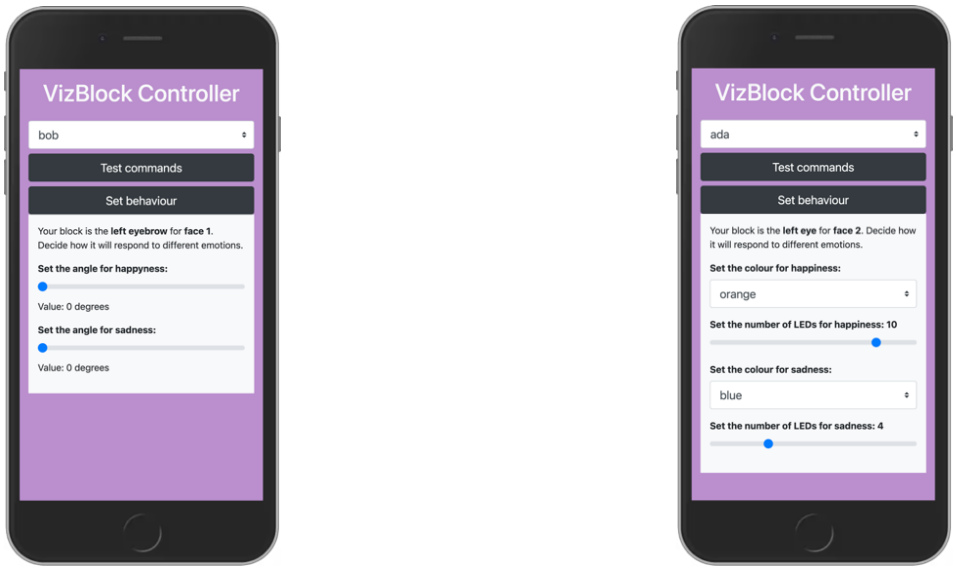

Figure 5: The student-facing web interface for controlling the Data-Driven Actor, including (left) a representation of how the interface controls motor behaviour and (right) a representation of how the interface controls LED behaviour.

feature using the web interface. The five facial features distributed throughout the classroom were then all physically brought together into one face. Next, the instructor led a conversation with the whole class about open-source datasets and demonstrated the second proof of concept functionality of the Data-Driven Actor, using it with a dataset of weather changes over time. Finally, the workshop culminated in theatrical activities, where the students were asked to begin designing characters that the Data-Driven Actor could embody, together with personas for these characters. They also began to write stories around the characters, including thinking about other datasets that might be used together with these stories.

4.2 Impact

Since its development, Civic Digits have used the Data-Driven Actor in their educational workshops with more than 2,600 pupils across the UK. Initially, all workshops were facilitated by members of Civic Digits. More recently, however, Civic Digits have developed extensive instructional materials to support teachers in running activities with the Data-Driven Actor themselves. In this way, they have been able to begin lending the kits to schools around the nation, accelerating their programme's reach and impact.

Moreover, the collaboration has had an impact on Civic Digits' business and creative development. Through the work on Data-Driven Actor, the company has been able to successfully trial a business model of offering a tangible product, in addition to a performance experience, to expanded audiences. Civic Digits' founder and artistic director, CD, has also been able to upskill in physical computing through the collaboration – learning fundamental processes like how microcontrollers are programmed, and how to connect and solder electronics. Beyond supporting her in further work on Data-Driven Actor and related projects, this process of upskilling has helped her to reflect on beginners' perceptions of computing, which has catalysed her to think more about how to make the educational workshops even more accessible to students and teachers.

The work has also led to a tangible impact for the academic researchers involved. The collaboration provided, accelerated and expanded the impact of our design research, as well as leading to new research agendas around creative computing education and co-creative research.

4.3 Future plans

In the future, Civic Digits plans to develop the Data-Driven Actor further in order to use it with a wider range of datasets, as well as with live data generated by audiences, for example data generated by filling out poll questions during a theatre performance. They also plan to explore the physical design of the kit further to enable the Data-Driven Actor to more readily express a wider range of emotions beyond happiness and sadness, for example shock or disgust. The goal of expanding the technology in this way is to make the kit into a more developed and open-ended 'actor' to be used as part of performances and learning activities with young people and other audiences, that can scaffold discussions about the implications of data.

5 REFLECTIONS

Having described the VizBlocks and Data-Driven Actor systems, and the outcomes of the collaborative work so far, next we reflect on the process of reimagining the prototype more broadly. The aim of this section is to consider what enabled the success of this work as well as how the design of VizBlocks afforded, and at times constrained, Civic Digits' vision. We address these points through 1) considering how openness and task ownership contributed to the fruitful collaboration, 2) describing the design factors that enabled

the reimaging of the prototype, 3) reflecting on the appropriateness of the technical infrastructure for Civic Digits' aims and 4) highlighting the potential of the flexible assembly enabled by VizBlocks.

5.1 Openness and task ownership in collaboration

As noted, the collaboration was fruitful for all involved, invigorating research agendas, shifting business models and leading to an impactful deployment of a new system. What made it so successful? One contributor was the openness of all parties involved. Both Civic Digits and the academic researchers entered the initially informal and open-ended collaboration without a set agenda; on both sides, key goals included learning about the other's practice as well as drawing inspiration for future work. This shared openness engendered a cooperative curiosity about how the existing tools might be reimagined.

On the other hand, without a set agenda or process, it was initially unclear who would take on particularly time-consuming and difficult tasks like technical development work, and whether and how the exploratory collaboration might lead to a fully developed and long-lived product. Here, the project's success relied on the willingness of individual collaborators to take ownership of emergent work packages. In particular, the work of EM, who is a Research Software Engineer, together with an external development consultant, was particularly crucial to enabling the Data-Driven Actor kit to be developed to a level of fidelity appropriate for classroom contexts. This entailed them rethinking both aspects of the form factor and the end-user programming interface, leading to the creation of a new web interface, as well as changes to the physical form factor (e.g., adaptions to encasings and making blocks wireless) to adapt it to a classroom context. These activities required approximately the equivalent of 3 months of full-time work, which was spread across the span of a year.

Ultimately, CD, the founder of Civic Digits, was able to secure funding for her own upskilling and expansion of the Data-Driven Actor, enabling her to gain confidence to lead the future development work so that the kit could be fully handed over to Civic Digits once the collaboration concluded. CD also took ownership of ensuring the sustainability of the Data-Driven Actor product, through seeking innovation funding to continue research and development, and seeking routes for further deployments of the system. In sum, initiative and resourcefulness of individual collaborators was crucial to the overall success.

5.2 Factors enabling reimagining of the prototype

As documented, VizBlocks was designed to be open-ended, ambiguous and customizable. Its core goal was to democratize creativity and experimentation while exploring and visualising data sources. However, while we were expecting VizBlocks to be used for the development of novel and experimental physicalizations, we had not foreseen it being used to develop new systems and use cases. It is clear that its openness, ambiguity and customisability enabled Civic Digits to view VizBlocks as a construction toolkit from which to develop new prototypes for unexpected contexts, similar to other purpose-built physical computing construction kits [3, 6, 7]. This was also supported by the fact that VizBlocks' functionality enabled rapid experimentation and testing of ideas – in particular, the middle layer of programming 'behaviours', together with the blocks' affordance to be augmented with design and craft materials, allowed for easy exploration of ways the system would respond to incoming data. Thanks to the reconfigurable, modular blocks together with the Node-RED interface, Civic Digits were able to rapidly create a high-fidelity, proof of concept prototype of the Data-Driven Actor.

Another factor enabling Civic Digits' appropriation of VizBlocks, was that the VizBlocks project and Civic Digits' intended project also had shared goals. The imagined use case for VizBlocks had many differences to the envisioned Civic Digits educational workshops; while the former was aimed at enabling wide audiences to create sculptural or spatial data physicalisations, the latter was aimed at supporting more constrained learning tasks around data literacy in a school setting. Nevertheless, both shared priorities in terms of enabling novices to creatively experiment with data, as well as capitalising on physical materials and performativity to harness this creativity and experimentation.

5.3 Appropriateness of technical infrastructure

Despite the success of the Data-Driven Actor, there is a question of how technically appropriate the VizBlocks system was for this particular use. Through the process of appropriation, certain aspects of the envisioned use of VizBlocks carried through, and others did not. Where we initially envisioned it as an open-ended system, for the workshops with school pupils, it gravitated towards a fixed physical configuration. Where VizBlocks might bring in multiple data-sources, Data-Driven Actor was primarily used with a particular take on facial expression recognition. These were pragmatic adaptions – there is a limit to what can be covered in a particular workshop, and a need to tailor interactions with systems to specific audiences. The use of real-time facial data addressed a common issue that we faced with VizBlocks, that it was often hard to find the 'right' data to use with the system – something meaningful, that could be easily experimented with, and that could be easily imported into the system. What did persist however was the idea that the blocks would be enhanced through physical materials, and that this was a key site for meaning-making and adaptation by end users.

5.4 The affordance of flexible assembly

The current instantiation of the Data-Driven Actor kit could technically be streamlined in the future to better serve Civic Digits' workshop activities and future plans. From another perspective however, the current Data-Driven Actor setup of creating a face out five modular VizBlocks blocks, could also be explored in the future through alternative set ups. While currently taking the form of a motorized face, the kit still allows for reconfigurable and flexible adjustments without any further training for Data-Driven Actor workshop facilitators.

However, there was much to be gained from VizBlocks' ability to foreground the technology as a fluid assemblage of parts [14] that could be interacted with individually but also brought together to be viewed as a bigger whole. The emergent process of disassembly

and reassembly of the Data-Driven Actor face into five separate interactive blocks for group activities in a workshop setting is also interesting to consider. Each group having control over one aspect of a whole, inputting different behaviors into their given facial feature (e.g., programming a left eye to blink, or a mouth to smirk) and 'decorating' each block according to the meaning they want to convey, offered opportunities for them to discuss about the provenance of data as well as how it can be represented. Subsequently reassembling the facial features together as a classroom, offered further opportunities for discussion, and for the workshop leader to synthesize each group's individual contributions into a broader reflection about data.

6 CONCLUSION

In this case study, we have documented the process of engaging in an initially unplanned and informal knowledge exchange activity between academic researchers and a local performing arts company. This knowledge exchange activity quickly became a fruitful collaboration during which a physical design research prototype was reimagined as a new product to expand the offering of a creative business. We have demonstrated how our shared attitudes and visions, as well as the initiative and resourcefulness of individual collaborators supported the project's success. We have also reflected on how a variety of design factors helped configure the Data-Driven Actor and the educational workshops into which the kit was incorporated. This included unpacking how the open-endedness, ambiguity and customizability of our initial prototype enabled us to think imaginatively about how it might fulfill a new purpose; considering how VizBlocks' affordance of flexible assembly configured the structure of the emergent workshop accompanying the Data-Driven Actor; and reflecting on how the pragmatic considerations of devising an educational workshop for school pupils constrained the use of VizBlocks. In sum, through this case, we have provided an exemplar of how the process of handing over and reimagining a prototype might unfold in practice. In so doing, we hope to inspire other researchers to explore bolstering the longevity and impact of their design research through industry-led and informal collaborations with small and medium enterprises with shared values.

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