

Building an Internet of School Things Ecosystem – A National Collaborative Experience

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ABSTRACT

Over the course of the next 10 years, the Internet of Things (IoT) is set to have a transformational effect on the everyday technologies which surround us. Access to the data produced by these devices opens an interesting space to practice discovery based learning. This paper outlines a participatory design approach taken to develop an IoT-based ecosystem which was deployed in 8 schools across England. In particular, we describe how we designed and developed the system and reflect on some of the early experiences of students and teachers. We found that schools were willing to adopt the IoT technology within certain bounds and we outline best practices uncovered when introducing technologies to schools.

Categories and Subject Descriptors

H.5.2 [Information Interfaces and Presentation]: User Interfaces.

K.3.1 [Computers and Education]: Computer Uses in Education.

General Terms

Design

Keywords

Participatory Design; Discovery Based Learning; Education; STEM Learning; Internet of Things (IoT)

1. INTRODUCTION

1.1 The Internet of Things

The IoT, a collection of physical sensors and actuators, which communicate via the internet, encompasses a variety of applications from personal exercise tracking devices, home

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heating systems and weather stations to performance indicators built into industrial machines. Its emergence in recent years provides an exciting space not only for industrialists looking to streamline their production costs [3] or for computer science researchers looking to develop ever more exotic transport protocols [8] but also for educators and students.

The emergence of the IoT has led to urban data becoming increasingly available, which allows new ways of understanding and visualising the connected city via its digital traces and data, both historical and real time [2]. The Internet of School Things (IoST) aims to build an ecosystem where students and educators can gain a deeper, empirically-based understanding of their environments and can actuate change through the use of the IoT.

In this paper we discuss our approach to innovating visualisations and interactions using participatory design with both teachers and students to create Project DISTANCE: Demonstrating the Internet of School Things - a National Collaborative Experience.

1.2 DISTANCE

DISTANCE originated as a consortium made up of 5 commercial partners, 4 universities and 8 schools with the shared vision that children are the creators of future digital data economy rather than just passive consumers.

This project explores the emerging ecosystem of IoT in schools helping teachers, students and businesses to share certain types of data openly. Students and teachers will be taught to measure and share data, using new IoT technologies, in ways that help make learning fun and enable students to investigate and address real-world, applied challenges using open urban data. This builds on projects such as the Participate Schools [4] and NQuire [6] where students carry out discovery-based learning with the help of supporting mobile and web technologies. Unlike its forerunners, the DISTANCE project is developing a co-created ecosystem which supports the collection of data from devices both within and outside the control of the individual.

In order to facilitate students' role as creators using the IoT an extensible technical and social ecosystem needs to be put in place integrating hardware, data, and associated content and services. This ecosystem should provide easy access to information, facilitate the interpretation of this data and empower students to take action on their interpretations.

2. METHODOLOGY AND PROCESS

2.1 Participants

Students and teachers from 8 schools spread across England took part in participatory design sessions run between June 2013 and February 2014. Primary, Middle and Secondary Schools all took part in the project. Teaching sessions took place within key stage 2 & 3 classes (students aged between 9 & 13, US equivalent of 4th-7th grades). Key stage 4 students (ages 14-16) also participated in the visioning sessions. Teachers from Maths, Science, Design & Technology and Geography departments took part in the design of the hardware, software and curriculum as well as subsequent teaching with the technology. Participating schools were selected to represent geographical, socio-economic, and domain-diversity across the UK, including schools in Lancashire, Birmingham, Suffolk, London, Peterborough, Liverpool and Bath and North East Somerset. This diversity was also represented in the range of prior experience with sensing technologies within the participating schools, from those with bespoke insulation sensors provided by previous innovation projects to other schools with only rudimentary provision of digital resources. The range of participant schools also translated into a range of teaching environments which varied from standard 60-minute classes of 30 students to bespoke “superlabs” of 200 students, as well as lunchtime learning clubs. In order to create appropriate technologies and content for these diverse contexts we used a participatory design approach which we will describe in the following section.

2.2 Methods Used

We used an iterative, mixed methodology across the eight-month design and pilot phase, including open-ended interviews, focus groups, training sessions, classroom observation, and shadowing. The participatory design process was defined as three phases aligned with the progressive maturity of the project: Conceptual (initial phase to explore baseline school cultures, expectations and use cases), Pre-pilot curriculum design (to further adapt envisioned use cases) & Iterative, in situ design (through action research). These sessions were iterative progressive stages, rather than distinct elements, tailored to the progress and needs of each partner school. In each, a slight variation of methodologies was used, including formal group design workshops, informal one-on-one design sessions, physical prototyping of digital data networks, teacher-led usability reviews, and illustrative comic strips to articulate students’ emergent conceptual frameworks of the IoT.

2.2.1 Conceptual

Participatory design requires an understanding of the predisposition, assumptions and contexts of the co-designing group. As we were co-designing ways to introduce and sustain an emergent educational technology, this understanding was particularly important in order to ground the unfamiliar concepts of the IoT within a meaningful and appropriate framework. This phase of the design process included more than fifteen two-hour progressive visioning workshops across the 8 schools.

Considering that the IoST could encourage a shift in current organisational hierarchies, the initial workshops were structured to allow students and teachers to ideate separately, to allow for the intentional creation of a safe, peer-to-peer environment for risk-taking. Once the initial use case concepts were generated, subsequent design workshops brought together both students and

teachers across all year groups. The “Conceptual” design phase allowed the team to identify IoT educational use cases that were both relevant and salient. The majority of the paper focuses on the following design phases, which refined these for actioning as curriculum or software within actual classroom settings.

2.2.2 Pre-teaching Curriculum

Prior to the deployment of the technology, a 4-hour participatory design curriculum development workshop was run in one of the schools with 6 teachers from the Science, Design & Technology and Mathematics departments alongside two of the consortium’s researchers. A number of data-sensing and broadcasting devices were brought along and shown in action so that the teachers would obtain a realistic impression of the devices capabilities.

Three pre-prepared exemplar lesson plans were discussed and enhanced and a new set of lesson plans were co-created to meet the requirement of providing enough scope to sustain 14 hours of teaching time to be carried out over seven two-hour sessions. A delivery timetable for the resultant lesson plans and support materials was agreed upon, ensuring teachers had adequate run-in time. An audio and video record was made of this event and transcribed to ensure all the requirements were captured.

2.2.3 In-Situ Design

Researchers helped facilitate and document the initial teaching sessions creating field notes, audio and video recordings. Teachers were interviewed before, during and after particular sessions and the findings were fed back into the development process. Improvements to the design of the curriculum and software were available for piloting in the upcoming sessions, where possible.

3. WHAT WE LEARNED FROM DEPLOYING THE IoST

3.1 Contexts That Motivate Students

A context-based approach, which was initially introduced in the UK with the aim to engage less academic students with science, uses applications of science in the real world as the starting point for the development of scientific ideas. Bennett et al [1] conducted a systematic review of the literature surrounding the use of context in secondary science suggesting this approach yields considerable benefits in terms of attitudes to school science and reduces the difference of attitudes towards the subject between genders. In order to engage students with the IoST we looked at applying a context-based approach when introducing the technology into schools. Initially the consortium identified four thematic areas around which to frame the IoST: Weather, Mobility, Health and Energy. We then used participatory design to define more specific contexts which would appeal and be relevant to students and teachers alike. The first phase of the design process focused on generating the most relevant ideas from the schools for use cases.

By providing safe spaces for discussions the team was able to elicit and understand the diverse personal contexts that could be used when applying the IoST to real-world challenges and in creating further engagement with the IoST in the future. For example, students in the second phase of the visioning workshops were asked to envision what type of data would be hosted by DISTANCE for personal safety. They began by identifying the hyperlocal context in which it was relevant to the school, i.e., a

shift in the timetable causing a situation in which the students could feel unsafe returning from school. Next, students considered what contextual data could be relevant to exploring school safety and which could be collected for their school (e.g. perceptions of safety, statistics on prior crime, mapping lighting zones to and from school). Students also explored what data could be both possible and valuable to access and share across the network of schools in the DISTANCE hub (e.g. commute distances, comparison of travel modes, availability of public transport). Finally, students ideated how this data could be aggregated to create a hypothetical school-based “danger” sensor.

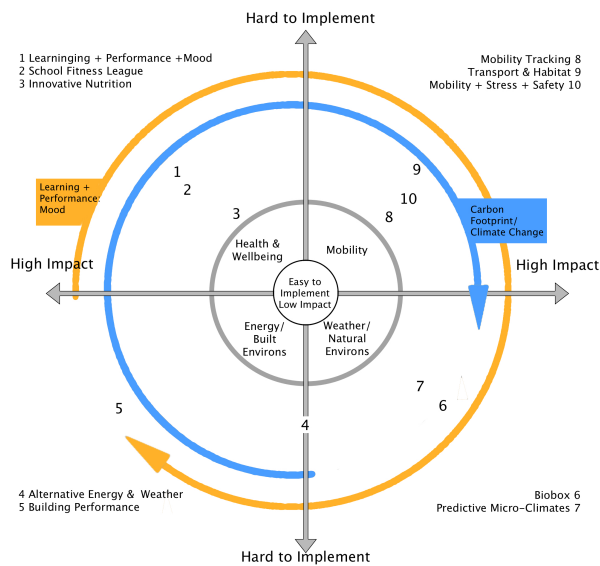


Figure 1: Map of key ideas from visioning workshop.

Figure 1 shows a map of key ideas generated by the schools during this two-month phase. Eventually, this was refined by the research team into 11 use cases which carried over to the Pre-teaching Curriculum design phase.

3.2 Giving Schools Tools to Visualise Data

A key part in the establishment of an IoST ecosystem was the development of platform(s), which allowed students and teachers to visualise, interpret and interact with the large amount of urban data available. Interviews with teachers and in-situ observation of students provided a number of key insights listed below.

3.2.1 Access to Contextual Data

The desire to explore contextual data, first observed in the visioning workshops, was further highlighted in practice when students started to compare data from their own school, which has a familiar context, to that of other participating schools. For instance, when students were trying to predict if the climate in Birmingham was warmer than in Bury Saint Edmunds, factors such as elevation, urbanisation and distance from the sea had to be taken into account alongside weather data. Initially, Google Earth was used in a separate window to provide this information. However an improved solution was developed which incorporated placing mapping and other information, such as descriptive statistics, side-by-side with the sensed data (Figure 2).

3.2.2 Reading from Graphs

A design decision was made to keep the onscreen clutter to a minimum by limiting the number of gridlines used when graphing the data. A consequence of this was that it was difficult to get an exact reading from the graph. For this reason a hover behaviour was introduced to present the x & y values (sensor & date/time) as a tooltip when a data point was highlighted (Figure 2). Initially the sensor value was presented next to the data point and the date/time was placed above it at the very top of the graph.



Figure 2: Displaying Data with Context and Hover function within DISTANCE Exploratory (App)

However this led to the graph being misread by a number of students with the date/time being confused for the sensor value. This was then redesigned so that data series name, sensor value and unit were provided on the first line of the tooltip and the date and time on the next line, which the students then found to be very intuitive. Teacher feedback was mixed as the hover behavior deviated from the standard paper-based experience of graphs, in which students practice the skill of reading values from axes. This skill is valued by teachers and is assessed in state exams. Teachers, however, readily acknowledged its practicality in allowing students to quickly interpret complex data, reducing drudgery and increasing enjoyment and playful exploration.

3.3 The Right Time

To develop familiarity with technology, teachers require free time in advance of lessons to explore new resources. Many teachers already have full schedules which constitutes a barrier to the adoption of new technologies. This highlights the need for intuitive, efficient technologies that allow discovery-based learning for both teachers and students in-situ. This would allow a progressive adoption of the technology without requiring intensive training or expertise. In this project we tried to address this issue by providing a number of intuitive and interactive tools to visualise and interpret data, as outlined in previous sections, alongside curriculum-related and context-based resources, such as lesson plans, presentations and worksheets which teachers could use with the new technology. However, in interviews carried out with teachers, it was suggested that more lightweight, upfront resources, such as tutorial videos showing how to make use of the technology could be used during the lesson to encourage student-led learning and problem solving and help establish a more collaborative learning hierarchy.

3.4 The Right Place

Key Stage 3 (US approximate equivalence of 6th-8th grade) is a space where schools in the UK are most comfortable in experimenting with novel technologies, in part due to the absence

of state exams. Consequently it is not surprising that a large proportion of the teaching which made use of IoST technologies took place here. One of the challenges in moving the use of the technology to other year groups is that teachers are concerned that the risk of obtaining an unexpected result is greater than with a tried and tested existing protocol. Time would then need to be invested into understanding how the unexpected result was arrived at rather than invested into content that is likely to be assessed. This is an inherent risk of discovery-based learning and not exclusive to the IoT. For instance, Tan et al report that 311 out of 485 teachers identified “Graphs/results obtained were different from theory” as a factor which deterred them from using dataloggers [7]. The Data Portal app has attempted to address this by enabling teachers to refer back to pertinent data selections via its permalink system (Figure 3). This allows students to access data and graphs that have been previously deemed relevant and illustrative of a theory.

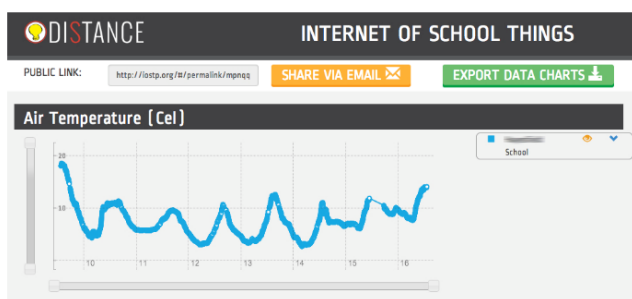


Figure 3: Use of permalinks in Data Portal app allows easy referral to data selections.

4. CHALLENGES AND OPPORTUNITIES

Creating an ecosystem where environmental data is readily available provides a new learning experience, which allows students and teachers to dive directly into the data being generated, stimulates open discussion and discovery and shifts time away from setup to higher-level learning activities in the classroom. A participatory approach to building a prototype ecosystem, encompassing hardware, software and services, was useful to begin to understand the specific needs of this context in order to reduce friction and increase engagement. The vision of encouraging educators, students and businesses to share data openly meant that how we designed the tools, using a collaborative and participatory approach, was fundamental in allowing schools to scale this idea on their own initiative. We found the process created value for schools, not only in terms of the tangible outcomes of curriculum content and software, but also in a greater sense of ownership over data, the development of a school-based digital identity within open educational data use and an increased flexibility to incorporate discovery-based learning. A unique aspect of this project is not just a focus on interactions in the digital environment, but the cross-over into physical environments, computing and other learning tools to create extended learning environments within and beyond the classroom. The hands-on nature of practical science lessons has been shown to enhance the learning experiences of students. [5] There is a danger that collecting data using sensors with a fixed position (and consequently very little need to directly manipulate them) will result in a drop in engagement and motivation. This needs to be examined and, if it proves to be the case, steps should be taken to include physical interaction where appropriate.

Sessions designed as part of the Weather Use Case already address this where students examine the measurement apparatus by trying to ‘trick’ a weather station. Building session materials which take into account the upkeep and periodic re-calibration of sensors would seamlessly embed these activities while also sustaining the infrastructure of the IoST. Facilitating student and teacher driven hardware development would also contribute to a hands-on experience. Strategies, tools and support materials need to be developed to ensure that IoST can continue to grow, fed by the teachers’ engagement to secure its legacy as a transformative technology.

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