ThinkActive: Designing for Pseudonymous Activity Tracking in the Classroom

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ABSTRACT
We report on the design of ThinkActive - a system to encourage primary aged school children to reflect on their own personal activity data in the classroom. We deployed the system with a cohort of 30 school children, over a six-week period, in partnership with an English Premier League Football club's health and nutrition programme. The system utilizes inexpensive activity trackers and pseudonymous avatars to promote reflection with personal data using an in-situ display within the classroom. Our design explores pseudonymity as an approach to managing privacy and personal data within a public setting. We report on the motivations, challenges, and opportunities for students, teachers, and third-party providers to engage in the collection and sharing of activity data with primary school children.

Author Keywords
Personal Informatics; Education; Classroom; Pseudonymous

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION
Public Health England (PHE) reports a sustained increase of obesity levels in school aged children, with obesity prevalence more than twice as high in year 6 (19.8% of 10 – 11 years old) compared to reception aged children (9.3% of 4 to 5 years old) [37]. Compounded further by issues of deprivation, PHE report that levels of obesity for children living in the most deprived areas are more than double that of those living in the least deprived areas. In response, regional charities such as the Newcastle United Foundation (NUF) deliver tailored programmes to primary school children (8 – 11 years of age) in an effort encourage healthy eating and active lifestyles into adulthood. Understanding the impacts of these interventions is crucial for regional charities to access additional funding, for schools to evidence physical education to governing bodies, and for students to improve their overall health. Evidencing the impacts of these programmes is possible through the use of activity trackers [27,30]. However motivating school children to engage in wearing these devices and interacting with such a programme [39] is a challenging task [29].

Within HCI, the design of systems which support self-reflection and self-knowledge has been addressed as personal informatics [23]. Personal informatics tools and mobile applications which support physical activity tracking (i.e. step-counting) have become commonplace [12]. Wearable devices (Fitbit, Misfit Shine etc.) are frequently associated with an installed companion mobile application. The design of these devices is predicated on individual, private, self-reflection, and emphasised by stage-based models of personal interaction with one's data [11,23]. However, when designing for a more public and nuanced environment, such as the classroom, these introspective models become questionable. Fundamental challenges exist around access to mobile phones during class, integrating into the rhythms of the school day [21], publically motivating students without shaming low achievers [25], and sharing sensitive student data between stakeholders in this space.

Researchers have begun to explore the design of personal informatics systems for the school environment [26,28,29] to encourage behaviour change through sociability between adolescent teenagers. Lee *et al* [19–21] leverage personal informatics to augment math and science lessons and improve data handling and personal informatics literacy. Existing studies have focused on adolescents [28,29], but have yet to design for primary school students engaging in personal informatics over a longer period of weeks. We extend those studies by reporting on the challenges of designing for engaging with younger students beyond researcher-led interventions, and by integrating with programmes delivered by charities such as NUF.

The Match Fit programme is typically delivered by NUF charity instructors to ~30 students during the school day, once a week, over a period of six weeks. Within these two-hour sessions, students undertake one hour of classroom activities followed by one hour of outdoor games. It was within such a programme that we incorporated ThinkActive – a system to encourage primary aged school children to engage in collecting and reflecting on their own activity

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tracking data through a situated display located in the classroom. We worked closely with the NUF, who have cultivated strong links with local schools, in an effort to design a system that the foundation could adopt in the future.

In this paper, we contribute the design of a classroom based activity tracking system that encourages social interactions around personal activity data. Our design explores the use of pseudonymous avatars as an approach to managing personal data within a public setting. We deployed the ThinkActive system over six weeks with 30 students at a primary school located within the top 1% of most deprived areas of the UK. Through interviews with students, teachers and instructors we identify the motivations, challenges, and opportunities for activity tracking within a classroom setting and offer reflections on our design for others working in this domain.

RELATED WORK

Within HCI, research around the experience and motivations of tracking began with the rise of the Quantified Self and Personal Informatics communities. Li *et al* [23] define personal informatics as systems that "*help people collect personally relevant information for the purpose of self-reflection and gaining self-knowledge*". Initial understandings of participating in the practice of personal informatics primarily focuses on individuals in the process of engaging in data collection and reflection for positive behaviour change (or health monitoring) [13]. Indeed, looking beyond short-term behaviour changing personal informatics, research has also begun to explore the longer-term motivations for engaging in this practice. Rooksby *et al* [35] describe our relationship with data tracking as *lived informatics*, within which individuals are motivated beyond simply quantification and improvement of self, and towards sociability of tracking and meaningfulness of data within different contexts [38].

Social Interactions with Personal Data

As personal informatics pervades both personal and working environments, research has begun to explore how the experience and meaning of personal tracking is situated in particular social contexts. Comparison between friends and colleagues is often achieved through social media integration [11] or in app friend networks. Personal informatics enthusiasts (*Quantified Selfers*) engage in face-to-face and online meetups to discuss their data collection methods and motivations [3]. Research has also begun to explore mechanisms to support social sensemaking [32], enabling individuals to reflect on shared activities through visualisations of aggregate personal data, deriving deeper collective understandings. Beyond reflection, Rooksby *et al* [34] demonstrate that we can design shared informatics tools to configure sociability through game mechanics such as turn taking. Indeed, existing work around promoting shared reflection through lived informatics [1,35] sociability, and exploring memories of data [8,9], attempts to extend beyond motivating behaviour change. This questions how we integrate data into our everyday lived experiences of sharing, reflection, and interactions. The desire to collectively understand and engage with our data more publically is beginning to emerge. Personal data outside of this model of introspection is relatively underexplored, especially within the context of education and younger populations.

Interacting with Data in the Workplace

Personal activity trackers have been used to collectively motivate behaviour change within the work environment as part of employer health and wellbeing campaigns [4,14,15]. Fish 'n' Steps [24] offered early insights into motivating behaviour change through collective activity tracking and public displays in the workplace. Overall performance was represented through a changing avatar to encourage individuals to maintain or improve the health of their avatar. Ubifit Garden [5] is positioned more as a mobile-based passive display to reflect on personal performance through the use of a living avatar that changes over time in response to activity levels, to reflect the individual. The use of avatars in these scenarios feature as the motivation to make positive behaviour changes. Instead we see avatars as an opportunity to create an anonymised identity, disassociated from the individual, allowing the student some control over their data sharing and privacy within the classroom. Social uses of personal data bring with it challenges of privacy and identity management, especially in the context of education and younger populations. However, shared metrics and graphical avatars are becoming a feature of the classroom through systems such as Class Dojo.

Pfitzmann & Köhntopp [31] offer us a formal definition of anonymity and pseudonymity; yet we prefer Langheinrich's pragmatic privacy principles (Notice, Choice and Consent, Anonymity and Pseudonymity, Proximity and Locality, Adequate Security, Access and Recourse) dealing specifically with ubiquitous sensing technologies [18].

Younger Populations and Personal Informatics

Existing public health activity tracker deployments with children primarily focus on inter-device accuracy validation [27,30], measuring student activity levels [6,17], or 'compliance' of wearing an activity tracking device [39]. Within these studies students act as data collection mechanisms for academic research and the opportunity to engage students in reflection of this data is often overlooked. Indeed, Farooq *et al* [12] posit "*the issue of why any changes take place is important but is a distinct question which is beyond the scope*", sentiments which are echoed within similar large-scale accelerometry based interventions with school children aged cohorts.

Designing for engagement with younger populations and incorporating personal informatics within the classroom comes with a responsibility to make careful designs. Preliminary work from Carrion *et al* [2] with adolescent teenagers outside of the classroom environment highlights the lack of personal informatics tracking devices designed specifically for younger populations. Competition-based systems within a more public school setting may motivate

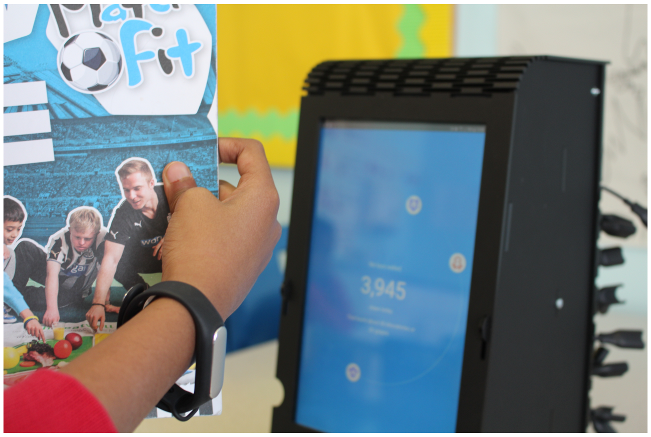

Figure 1. ThinkActive base station, tracker and workbook

only top performers, providing little motivational support for other students [25,26]. Alongside the challenge of engaging students with such a system Lee *et al* also discuss the issues of designing around the constraints of the school day [21].

Stepstream [28] uses games to encourage adolescent teenagers to collect activity data and interact with online social activity feeds between classmates. Students used real identities within the system and synced their data in an afterschool session each week. These online and offline sessions attempted to motivate ongoing interaction and data collection with the Stepstream system. This self-sustaining strategy of simply 'hanging out' with friends during these specific sessions hoped to encourage students to engage in discussions around their data and reflect on their own behaviours. Within our own study we are extremely conscious of not just measuring activity levels but rather encouraging children to reflect and socially interact around data discussions in the classroom. Early work from Lee [19–22] discusses how the Quantified Self (QS) provides an opportunity to engage students in higher level learning about their own behaviour through a shared classroom activity focused on observing a single portrait of an individual's personal data. Lee [19] presents specific tensions between the personal nature of informatics and the public space of the classroom. This is complicated further by the desire to share and learn together using personal data in this context.

The collection and analysis of data also extends beyond the purposes of reflection for the individual or cohort and into the realms of higher level understanding across populations. Indeed, Greller and Drachsler [16] identify the potential for educational data to become a powerful means to support learners, teachers, and other institutions in understanding and predicting personal learning needs and performance. Within the Learning Analytics framework [16] the authors describe how we can begin to use this data in aggregate for the purposes of evidencing practice and supporting curriculum and student development goals.

Our approach aims to understand the motivations, challenges, and opportunities for students, teachers, and third-party providers to engage in the collection and sharing of activity tracking data with primary school children. Embedded within our approach is an attempt to integrate into the delivery of programmes by charities, such as the NUF, and facilitate ongoing collaborations between schools, charities, and researchers through the data resulting from these technologies. Ultimately, we hope to inspire students to explore what it means to be a digital citizen in an age where data is ever prevalent.

NEWCASTLE UNITED FOUNDATION PROGRAMME

We had the opportunity to develop a digital component for Newcastle United Foundation's six-week Match Fit programme working with a class of 30 primary school children (aged 8 and 9) in the North East of England. NUF is a charity run by the English Premier League Football club of the same name. In 2016 the charity delivered programmes to 50,000 participants, with the Match Fit engaging 4595 children from 126 local schools. Match Fit was well established and had run for the past three years at the school we engaged with. Weekly two-hour sessions are led by two of the charity's instructors. The first hour are classroom activities to increase literacy of healthy eating, and the second focuses on outdoor physical activity. The programme is structured by exercises in a paper workbook kept by each child and topics include nutrition and human biology.

THINKACTIVE OVERVIEW

The system consists of a classroom situated base station (Figure 1) through which pupils synchronise their step data derived from a personal activity tracker. The base-station has an always on display that shows class goals and challenges, and progress made towards them. To access and sync their step data, students scan a QR code on their workbook.

Each pupil uses a Xiaomi Miband Activity tracker a wrist worn activity tracker. It is a relatively inexpensive ($15) accelerometer based pedometer, that communicates activity data using Bluetooth (BLE). It has approximately one month's storage and similar battery life. The activity tracker does not display a step count; three status LEDs show only abstract information; the unit vibrates when a target number of daily steps is reached. The affordable price, long storage, and infrequent need for charging make it highly suitable for a deployment of this duration in a school environment.

The base station contains a 10-inch Android tablet and a USB hub to charge the activity trackers. The acrylic enclosure exposes the screen, camera and the power button of the tablet; it presents the charging points for the activity trackers at the rear. The base station also manages interactions with the activity trackers via Bluetooth. The Android application comprises of a web application interface and a native set of background services to perform low level Bluetooth data transfer, data storage, and remote management. Step data is stored in a local SQLite database that is periodically synchronised with our remote server. We used Google Firebase Cloud Messaging to enable remote management (database management, and refreshing the web application

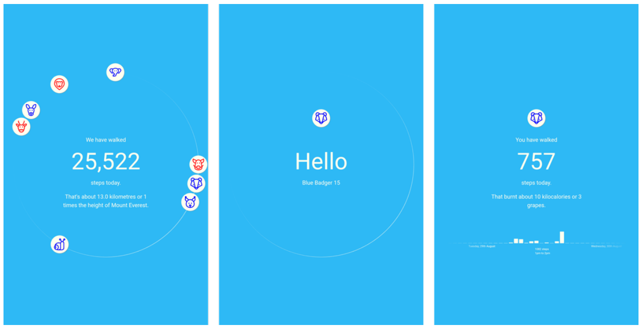

Figure 2. ThinkActive views (i) Class view (default display), (ii) Greeting view, (iii) Profile view

component). The tablet used 4G mobile data, mitigating any infrastructural difficulties at the school. The application has two main views: (i) a class view in which an overview of the current challenge is shown and a (iii) profile view through which an individual interacts (Figure 2). The display defaults to the class view. If an activity tracker is nearby, the associated pseudonymous avatar appears on screen – in this way a crowd of characters assemble.

We attached a unique QR code to each Match Fit workbook that identifies a student's pseudonymous avatar. To authenticate, they simply hold up the QR code to the base station camera which then triggers a connection attempt for the associated activity tracker. The base station requires that both the QR code and activity tracker must be present and within range of the tablet to successfully authenticate. In this workflow, the child doesn't have to manipulate a keyboard or remember login credentials. Once the connection with the activity tracker is made, the activity tracker briefly vibrates; a small but satisfying micro-interaction [36]. The base station then displays a greeting using the pseudonym and avatar, reads and displays their battery level and initiates the synchronisation of step data with their activity tracker, before displaying their step data and contribution to a class challenge. If a low battery level is found they are advised to seek the help of the teacher to recharge. There are no shortcuts; to view your data you must synchronise your data.

There is no electronic record of the association between students and pseudonyms; only the teacher in their role as guardian of the children has this information recorded on a *paper lookup sheet* and kept in the classroom. In this way no other stakeholder can identify the children from the data.

MOTIVATIONS AND DESIGN CHALLENGES

The ThinkActive system was developed through a series of interactions with NUF; both in observing the current format of three Match Fit sessions in nearby schools and through interviews with their instructors and class teachers – with an agreement that we would trial the platform during the subsequent school term. The content was then developed incrementally and the interactions refined over an eight-week period (six weeks of the programme, plus two weeks prior to it).

Taking the perspectives of the three stakeholder groups (NUF instructors, teachers, students) we identified the key motivations and opportunities that the system would afford each. The activity trackers would allow NUF to evidence the efficacy of the Match Fit programme; such that they might improve their practice and seek further funding from health organisations. The ThinkActive system (in combination with Match Fit) would support the teachers to deliver key educational messages; supporting science and math specifically. For the students, this would be a fun and healthy activity, with opportunities for competition and personal reflection, whilst developing their data literacy. As HCI researchers our academic interest was in the design and deployment of these technologies within this complex interplay of stakeholders.

Primarily our design challenge was to develop a system that could be practically deployed at the school for the duration of the study and integrate into future Match Fit programmes. It needed to run continuously making only careful demands of the pupils, teachers and school's time without requiring arduous technical support.

Deployment

Typical deployments focus on a single personal activity tracker associated with an individual's personal device. This model is not suitable for younger children in a classroom setting, where the majority do not have access to such a device. Providing students with their own device also raises a series of issues such as, prohibited to access devices during lesson, unmoderated access to the Internet, and expense. This was especially evident in a deprived area with a school under financial pressure. The potential for loss, damage and technical support also makes this requirement undesirable. A single shared device simplifies our deployment while allowing us to explore potentially performative social interactions around a public display. Such an economy also makes this suitable for future deployments at scale. The activity tracker's affordable price, long storage and infrequent need for charging, made it highly suitable for a deployment of this duration in a school environment.

Given that we were designing for children as young as 8 years old, research has shown [33] we need to design for simplicity and the inevitable fallibility of memory. Indeed, previous studies suggest that even for adolescent students, usernames and passwords add an administrative overhead that required extensive researcher intervention [28]. With this in mind, our approach to authentication made use of unique QR code affixed to the back of the Match Fit workbook that was stored in the classroom.

Engagement

We hoped highly engaged students would not only produce the data we needed, but also take care of their activity trackers. Our assumption was we would likely have to replace around 20% of the activity trackers over the period of the study, indeed existing studies had pedometer loss-rates of ~50% in high school cohorts [28]. While engagements of this duration are difficult to establish and sustain [29], the structure of the primary school day and programmes such as Match Fit offer us opportunities to facilitate this. The UK school day routines of primary aged is highly structured; regulated by bells – typically in a single classroom, with the same classmates and with a consistent teacher for all subjects. The Match Fit sessions were delivered at the same time each week, by the same instructors, split between the classroom and the playground. This routine and well understood school environment allowed us to make a deliberate intervention to keep the study present in the children's everyday lives.

We chose to design a deliberately active process for transferring the step data from the activity trackers to the base station. This synchronisation could have been achieved as a passive background process without the explicit interaction of the pupil – simply by them being in proximity (as in [28]), but we preferred to motivate regular consequential interactions that contribute to a daily or weekly class challenge. Our design challenge was to ensure that the students remained engaged and that activity trackers were worn for the duration of the programme, in order that the data be produced. Then to recognise that once produced this data created a personal asset, a detailed picture of an individual to which others may or may not be granted views of. The data has social value to be shared or restricted.

Our intentions were to design a system that could become integrated into the school day without becoming overly disruptive during lessons. This requires a carefully applied degree of presence.

Supporting the Curriculum

The base station allowed us to support a variety of educational outcomes; designed with reference to the UK National Curriculum, Key Stage 2. We explored this in the challenges, where abstract step counts were translated into more relatable quantities. We either showed the step count as distance (miles or kilometres) with an associate quantity (nine times around St. James' Park, half way to York, etc.) or as energy (in kilocalories) with an estimated quantity of food (three bananas, etc.). Basic numeracy was reinforced through the presentation of some very large numbers (formatted with commas). The battery level allowed us to use percentages and the distances to places was support by simple fractions. In week five we introduced an interactive bar chart view (Figure 2.iii) for an individual to see the history of their steps, over the period of the study, at an hourly granularity.

Identity Management

We chose to create a unique pseudonym for each pupil to act as their ThinkActive identity, known only to the pupil and their teacher. In designing the unique character pseudonyms, we needed a generative scheme that could scale beyond this single study. We settled on using a set of 49 animals in combination with a modest set of colours and number range (Blue Badger 15). This enables tens of thousands of unique avatars to be generated. For this deployment, we ensured that within the class the allocated animal was unique, that half were allocated red and half blue, with a number between 1 and 15. The artwork for each animal was a simple outline of the animal face – we wanted each character to be as far as abstract as possible. We excluded those we judged to have negative associations, for instance the sloth.

For our purposes, it was sufficient to collect only aggregate measures of the class' activity. We took the decision to collect no personal details: names, ages, heights, etc. Yet we recognised that for the individual the data had a value to be reflected on privately or selectively shared with others based on friendships and judgements of trust. These are issues of a pupil's identity management with respect to the different stakeholders in the study, including ourselves.

THINKACTIVE DEPLOYMENT

Two weeks before the start of the Match Fit programme each student was given a letter to take home to parents inviting them to an afterschool session and informing them about the study. We also included a consent form for their child to take part in the study which had to be signed and returned before we included them in the study. We gave a verbal briefing to the parents at the afterschool event and framed this project as an experiment; a trial process in which they were all involved. The activity tracker was presented to them inside of a box that also contained an information sheet that we had produced concerning the care and maintenance of the device. It also included their unique character name and graphical avatar – which the children were told would be their identity during the study. Our electronic records were only associated with these pseudonymous identities, only the teacher had a *paper lookup sheet* of which identity belonged to which pupils. The activity trackers were set to vibrate when the student reached a goal of 3000 steps – a modest daily target that we expected most children to achieve.

The Match Fit lessons took place during the school day within a two-hour period on Tuesdays in the same classroom with a one hour in-class activity followed by an hour of active lessons delivered by the instructors. At the first Match Fit session we accompanied the instructors; during which the children were given their workbooks, through which Newcastle United Foundation structure each lesson and record pupil contributions. These books were kept in the classroom, accessible to the children during the school day. We produced a sticker to be physically attached to the book, containing the character name, graphical avatar and a unique QR code. We wanted to strongly associate our intervention with the existing Match Fit materials and processes.

Shortly after the third Match Fit session we delivered the base station to the class. As we had hoped, it found a home at the back of the classroom on a dedicated table and left on throughout the day. The workbooks used during these lessons were placed next to the ThinkActive base station which allowed students to access the system at any time during the day without supervision. Over the remaining three weeks of the Match Fit programme we published a variety of weekly and daily challenges to the class, via the base station. The distinction between the Red and Blue animals allowed us to introduce an element of competition; either as an absolute reflection of total steps of the two groups or as an average number of steps of each. We intended that this would create some social encouragement for teammates to synchronise their steps and make their contribution count. After the final Match Fit session and conducted the interviews with the pupils, teachers, and NUF instructors.

THINK ACTIVE USER STUDY

We deployed ThinkActive with primary school children (n=30, 16 females, 14 males) in a Year 4 class (aged 8 – 9) within the North East of England who were undergoing the six week Match Fit programme delivered by NUF. In response to the strong correlation between childhood obesity and deprivation [37] the foundation targets schools in deprived areas to increase literacy around healthy eating and active lifestyles. The school is situated in an area of high levels of deprivation and is ranked within the top 1% of the most deprived areas in the UK according to the Index of Multiple Deprivation 2015 [7].

Our findings are derived from observations from the full six week Match Fit delivery. The research team also took part during the lessons to sensitise ourselves with the programme's content as well as to understand the student's engagement with the ThinkActive system. At the end of the programme we conducted semi-structured interviews with the instructors (n=2, males), teachers (n=2, males), teaching assistant (n=1, female), and a self-selected group of students (n=4, 2 males, 2 females). The interviews with the teachers and instructors were held face-to-face at an office in the school. We spoke to the students in the classroom during break time. The interviews lasted between 32mins and 1h30mins and were audio recorded and transcribed. Both primary and secondary authors then coded the data and thematically analysed the transcripts.

FINDINGS

Our findings are derived from usage data, observations and interviews with the students (S1, S2, S3, S4), teaching staff (T1, T2, T3) and instructors (I1, I2) during and after the study. We describe the findings from each stakeholder's perspective and map them to our original design challenges, finding the principal themes of *engagement* (engagement), *data as a personal asset* (identity management) and *study appropriation* (deployment, supporting the curriculum).

Students

Engagement: Our first measure of engagement is that the activity tracker was worn, maintained, and collecting data. On each of our visits to the class many of the children would enthusiastically greet us – proudly showing us that they were wearing their activity trackers. Several children reported that they almost never took them off – S4, "*I wear it every time when I'm sleeping, but if I'm in the shower or swimming pool or beach I take it off*". In each session we observed that typically one or two children would not have them on. Somewhat surprisingly, only one activity tracker was misplaced by a student early on in the study. The remaining students continued to wear the activity trackers for the remaining period with 80% of students wearing them for 32 days or more. The students reported that there were some students who engaged with the system above and beyond casual behaviour. We asked S2 how often he used the base station, and S4 interrupted, "*He's addicted!* [*He syncs*] *every time he sees it!*". S2 replied, "*Maybe 5 times a day […] I go only when I come into the class when it's break-time, when it's lunchtime and when school is over.*"

Figure 3 shows the number of children that interacted with the tablet to transfer their data on each day after the base station was introduced in week three. In this figure, we demonstrate the continued engagement by the majority of students during the deployment in the classroom over the three-week period. We also show that the students interacted with the base station outside of the weekly (Tuesday) session and permeated into the normal school day. The size of each circle represents the number of interactions a student had with the tablet (1 – 8), while each colour represents a different weekday. Almost 80% of the 29 students interacted with the tablet for at least 5 days, with the most active student (S8 in Figure 3) interacting on 13 out of the 14 deployment days. There are at least 10 students interacting with the tablet on each day apart from Thu 13.

The vibration of the activity tracker associated with the accomplishment of the daily target was mentioned frequently. Prior to the deployment of the base station this unknown quantity was used by the teachers to set the students a goal of getting the band to vibrate earlier than the day previously. This meant that children were trying to achieve a goal of 3,000 steps before a set time without knowing their step count i.e. walking to school, before break-time, or lunch time. The teacher had even incorporated the vibrate feature into a class joke. S3, *"[T2] said that if you do 3000 steps then you'll get an electric shock! Yeah, but I didn't believe that!*"

Data as a Personal Asset: We observed children using the base station and writing their daily step totals on the back of their hand, so that they might then tell their friends or family. The activity tracker has no numerical display so this had to be obtained from the base station. Despite this added workflow of syncing the data through the base station, it was clear that the children felt at ease in interacting with the device independently, managing their time around the school day. Both teachers and students were happy to interact with the base station before school, during break time or lunchtime, as well as afterschool. These interactions rarely took place in lesson time.

The children told us that the challenges motivated them. We asked S2, "*Why did you sync your data so often?*" – S2, "*I wanted Reds to win!*". There was some confusion about whether by transferring the data more often would result in

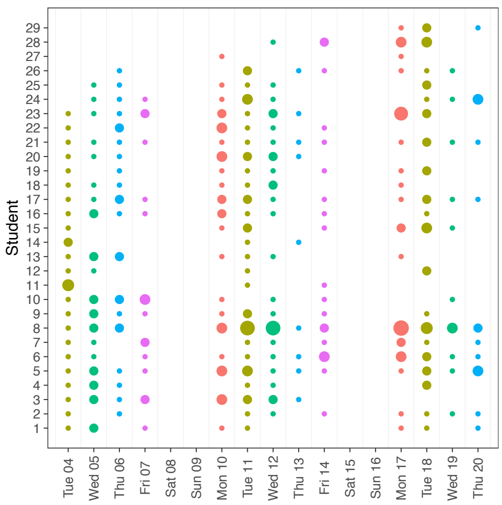

Figure 3. Frequency of student interactions with base station

more steps being counted. S3 demonstrated that he understood the system, "*When you scan yours and it says 5000 steps and you scan it again and it say 5035, it only adds 35 not 5035*".

The children reflected on how their activity trackers had been seen by the family at home. Beyond the classroom the children were talking about their step counts. S3, "*When I said the Blues had beaten the Reds then my mum was proud of me […], but when the Reds beat the Blues then she said maybe you should do some better steps.*". For many it seemed a matter of pride, one even reported that their sister had cried because she did not have a "*fitbit*".

The use of the avatars as pseudonyms was popular and well understood by the children. Some students had also grasped the implications of being pseudonymous. S3 told us, "*I think the avatar is helpful because it kind of great to be anonymous [but] my friends knew [who I was].*" Although some students were aware of their friend's daily step counts, when asked about who often had the highest in the class they were unable to identify a specific student.

Teaching Staff

Engagement: The teachers witnessed the pupil's use of the system and their social behaviours around it. T3, "*Some children want to do it when they come in - playtime, dinnertime, after sports constant. […] if they are lining-up at lunch, [they ask] 'how many steps have you done? I've done 5,000.' It's good*". The teachers echoed similar sentiments from the children in that syncing process with the base station became a social interaction that was shared between friendship groups.

Data as a Personal Asset: The teachers were the only stakeholder who held a record of which pseudonyms belonged to which student. While they agreed that the characters had worked well, T2 said, "*I'm not sure it would need to be anonymous. I think most of knew who everyone else's character was by the end.*". Although the students suggested this is not the case in interviews.

Using the activity data to evidence teaching interventions with the children was also a key motivation for engagement in the system. As T1 demonstrates - "*A PE co-ordinator [could] say, 'These are the kids that we have trouble keeping them active. This is what we've tried to do about it. This is the impact.' That would be then shared with Ofsted and the governors and everyone else within the school*". They could use activity data to evidence their targeted and differentiated approach to physical education across an ability spectrum when reporting to governing bodies.

Study Appropriation: In our initial letter to parents we were clear that we would both replace any lost activity trackers, without a monetary fine and that the activity trackers should be worn for "*as much time as possible*". After just a day, one child lost their activity tracker. The teacher decided to make an example of them and their activity tracker was not replaced. Their stated purpose was to teach the children about responsibility. In addition, the teacher would regularly ask children to show that they were wearing the activity tracker and highlight those who were not in class. T1 told us in interview, "*Because we were quite like, 'We're doing this. You must have it on.' […] some guys wanted to take it off, so we said, 'Don't ever take it off. It's not going to do any harm.'*". The teacher's investment in Match Fit and ThinkActive is a significant factor in the maintained engagement of the children. The physical token of the activity tracker, made participation obvious to teachers and pupils alike.

The teachers also found ways to become involved through their own devices. T3, "*It's motivated me, I've got a little challenge on my phone with them, […] they're competitive […] 'how many steps have you done?' – everyday! So, I have to show them [the app] and then calculate how many times theirs has vibrated and then they'll go on to the device and they compare that – they love it!*". Engagement from the teachers between themselves and the students further highlights the sociability of these form of interactions. Similarly, we hadn't anticipated the inclusion of other stakeholders as part of this process.

Instructors

Engagement: Our approach to incorporating ThinkActive into the Match Fit lessons was to act as an additional resource, promoting wider student reflection and participation in the discussion around their own activity levels. Indeed, we witnessed both Match Fit instructors regularly referring to the activity trackers and ThinkActive in class and the students associated these components with programme. I2 told us, "*The first week […] when we came in […] they came running through the hall […], 'I'm wearing it! I'm using it!'*".

The instructors discussed the positive social aspects of the pseudonymous avatars - I2 told us, "*kids who were in* *friendship groups probably did share the characters […] so they could work it out. But if they didn't want to share that, they didn't have to*". Similarly, the instructors also referenced their cursory de-anonymization of a student - I1 "*It would be, like, 'Oh, has Blue Elephant recorded the steps?' And Blue Elephant would stand up and everybody would know who Blue Elephant was. You ask me in two minutes who Blue Elephant is and I wouldn't have a clue*".

Data as a Personal Asset: Showing the positive effects of Match Fit through the students' activity data was the NUF instructors' primary objective for participating in the study. As I1 points out, "*part of it for me is actually that evidence base that we can use elsewhere […] using that for potential new funders to come in and say, 'This is the difference Match Fit makes, here's some real hard evidence that we've collected […]*". Using this data as evidence to subsequently access additional funding was paramount. This meant that they were invested in ensuring the students wore their activity trackers for as long as possible so as to collect as much evidence as possible. However, it became clear that the granularity of data that we could make available, at a minute by minute basis per child, would go far beyond what would make a compelling statistic for their funders. As such, the instructors discussed representing this data in aggregate overview rather than on an individual student basis - "*I think averages, or weekly averages, will probably be more beneficial than actual hours because it'll differ between every single kid*".

This transient understanding of a student's identity is important as it affords multiple actions. Within the classroom instructors are able to refer to an individual's data in a friendly way whilst maintaining anonymity if desired. Outside of the classroom the avatars abstract individual students and provide a means to report on this data to funders at an anonymised individual or cohort level. NUF need store no personally identifiable data on their systems. Additional, the avatars gave the instructors a way to raise concerns about children with the teachers, without breaking anonymity. As I1 said, "*It just got rid of all the safeguarding sort of concerns around bullying that could have come from it; the stigma attached to the kids who weren't doing as many steps; people who were maybe, like, letting the class down by not doing steps towards the target – that was pretty important, really. […] and their family wasn't going to be chucked in the spotlight as a particularly unhealthy family*". Had the data reflected potentially concerning behaviour, I1 said, "*That's something we could potentially highlight to the school and say, "We have the data set and, by the way, we know that child 'x'[the pseudonym] has been up during the night and done all of this.*" The instructors then suggested that the system need only report the student's steps at daily granularity, at which this kind of detail would not be apparent and would not be cause for their concern. As part of this discussion we emphasize the need to consider both the granularity of activity data as well as the hours of collection for younger people. This points to a structured approach of sharing data with different levels of granularity between stakeholders, depending on their needs.

Study Appropriation: The instructors were keen not only to promote activity but also to reinforce life lessons in competitive play. In the final weeks they used the current ThinkActive challenge in class to motivate students. I2 said "*I think it's part of our job, it's really important for us to teach kids how to lose. And it's very difficult to do that as well. You've got to incite a little bit of competition because they need to learn that things don't always go their way*".

In week four of Match Fit we ran a challenge which counted the number of steps the class had walked over the week. By the end of Friday, the total reached over a million steps (1,080,719, ~340 miles). NUF publically tweeted this milestone, which was retweeted by the school, the football club and local health charities – a combined audience of over one million followers. The step count, with a little context, was being used as a rhetoric to reflect positively on these organisations – outside of ThinkActive system.

We also discussed how this data might also become evidence in regard to performance management; both of the individuals and the Match Fit programme as a whole. Instructors acknowledged that, "*if there was a complete anomaly in the data against a member of staff, it would be something to look at. But I can't imagine it happening.*" As well as "*It could prove that what we're doing doesn't work.*", I1. It should be noted that the instructors were both at a senior level and perhaps overlooked more junior instructors who might well be measured by this metric.

Summary
Students maintained their engagement with ThinkActive and formed social groups to experience their data. Teachers observed students forming routines around the system and engaged students in competitive step counting. Teachers and instructors both emphasised the potential for data to act as evidence either for additional funding or to make explicit their efforts in delivering interventions. Both stakeholders also used the activity trackers as a means to teach life skills such as taking responsibility for your actions or learning how to lose in competition.

DISCUSSION
This research attempts to understand the complexities of engaging primary school aged children in personal informatics within a classroom setting. Our findings demonstrate that personal informatics, in this multi-stakeholder context, extends beyond motivating behaviour change. We now return to our design challenges as criteria for success and offer insights for others to draw upon.

Deployment
Our findings demonstrate that the design of ThinkActive was well suited to the classroom environment and did not negatively impact upon the routines of the school day. Integrating within this environment meant that we also had to work within the existing routines and social structures

between stakeholders. Rather than enforcing our own policies, i.e. access to and placement of the base station, we wanted to work within the complexity of the classroom to become aware of potential challenges presented by deploying technologies in this environment. Indeed, we observed independent patterns of use at key points throughout the day, outside of adult-led instruction. Similarly, our design had to integrate within the ongoing Match Fit programme without undermining its delivery and reputation, at present and in future deployments. While the Match Fit programme structured our deployment, our design also had to extend beyond these sessions and operate independently without researcher or instructor intervention.

While our chosen activity tracker lacked a display, this simple device remained compelling to students. Receiving haptic feedback when achieving step goals motivated ongoing engagement and moments of excitement. The process of scanning the QR code to access and synchronise activity data from the devices proved straightforward and was quickly adopted, requiring minimal administration of user credentials. Further, the single point of interaction via the base station created a focus for sociability. As the display was at the back of the class, the act of syncing data was public, yet the details of the interaction were only seen by those directly in front of the display. The size of the display was small enough to act as a personal device, to reflect on personal data, but large enough to be a public interface to encourage interactions between friends. The device's placement within a shared environment along with positive encouragement from the teacher allowed for ad hoc interactions and moments of sociability. Students discussing this in the lunch queue and writing their steps on the back of their hands and comparing themselves with the teaching staff's activity trackers, highlights these interactions.

An alternative approach to the deployment of such a system would have been to define the roles and responsibilities of each stakeholder, designing specifically for this controlled scenario. Instead we wanted to understand more of the environment that exists and uncover some of the practices that would challenge future larger scale deployments, where we had little or no control.

Engagement

The combination of an affordable device, a publicly present display, an active synchronisation process, and daily challenges led to high levels of engagement and sociability between stakeholders. Our design differs in these respects from existing classroom-based interventions. In the case of Stepstream [28] the research team led sessions to encourage socialising around personal data. Within our study we encouraged similar social interactions by making the synchronisation an active process that was public and performative. This encouraged student-led informal interactions and conversations around personal data. The configuration of the data synchronisation and the step challenges make for a dynamic system that changes over the period of the day. Around this we found that routines formed. Importantly engagement went beyond the weekly Match Fit sessions and became part of the class' daily conversation without becoming a disruptive influence.

In our deployment, the step challenges were set by the research team and our findings demonstrate that this motivated engagement with the system. Future work might provide students, teachers, and instructors with the ability to create their own challenges to enhance this experience. Designs should consider incorporating each of these stakeholders into the process of activity tracking and use reflection as a way to encourage social interactions around student activity data and motive long-term engagement.

Supporting the Curriculum

We addressed this design challenge by providing the teacher with anonymised activity data for use in maths and science subjects. Data ranged from simple step counts, to estimates of calories and distances (in different units and scales) to weekly activity graphs. Graphs can not only be used when teaching students about charts, but also when teaching topics such as creative writing where students can write the story of their activity chart for a week for example. We ensured that the data was suitable for students of this age and curriculum level. As Lee *et al* [22] discuss, students are more likely to engage with learning when working with their own data than with some fictional examples.

Existing research has explored how personal informatics can be used as part of a researcher-led design activity [22]. However, we are mindful to encourage teacher-led delivery of this data to support other learning activities in class beyond our study. Future research might explore the use of this data in both raw format (i.e. daily step counts) and as a prescriptive classroom activity (i.e. data story) to understand how this provides teachers with opportunities for future appropriation.

Identity Management

Pseudonymous avatars were a pragmatic response to our design challenges and played a valuable role for all of the stakeholders in the study. More broadly, pseudonymity affords the individual the ability to socially negotiate access to their identity that a real name would not. It also ensures that any data associated with a pseudonym is therefore anonymized through abstraction at the point of collection. It allows for data to exist in public yet be *disguised*.

An important factor in our design was to encourage reflection and sociability between children, staff, and instructors about their data. Our design demonstrates that existing notions of *personal* within informatics can be reconfigured to adopt a more *public* model of interaction and understanding. Pseudonymity affords a more public discussion and learning between children around the range of differing behaviours without comprising their privacy.

We found that over a relatively long period of time, students of this age, do not become aware of all the identities within their class. Where a third-party learns the identity of a pseudonym, i.e. within a Match Fit session, we have found that this is only briefly remembered. The student is only temporally de-anonymized in a social context. Alongside this, students actively engaged with the public display within small social groups and traded results between friends. This demonstrates that identity is socially negotiated and students are able to control with whom they share. More practically with our study, we found that teaching staff and instructors agreed that the use of pseudonymous avatars reduced the potential issues of stigmatization and bullying in the classroom. The instructors were also focused on ensuring that both the student and their associated family were protected from these negative effects and potential public shaming or negative judgements of parenting.

Our approach leverages the sociability of playful avatars and provides students with the ability to selectively share their identity with peers, without the need for a heavy-handed approach to access control through hardware or software. We do not suggest that pseudonyms provide complete anonymity, but rather a more negotiated model of identify management. Pseudonymity affords an openness to activity tracking and can be used to promote sociable reflection within a complex public setting such as the classroom.

Designing Pseudonymous Avatars

Our simple animal-based graphical avatars allowed students to adopt a playful identity, which the impacted the way the system was perceived. Importantly these avatars were easily identifiable both graphically and linguistically (i.e. Red Octopus 5, Blue Badger 15). The structure of our allocation meant that within the class each student could be identified by animal alone (with the colour and number absent) and their avatar need not display the number. Our use of colour gave two sub-groups around which there could be competition – in easily understood and visually grouped categories. To allow pseudonyms to be used both graphically and in conversation, we recommend that there should be both a textual and a graphical rendering which are tightly coupled. The association of a colour attribute to an object is a convenient means of achieving this. However, simple mappings between real names or commonly understood personal attributes should not be used. These are all factors that designers can use to create a memorable pseudonym.

Using Pseudonymous Data

Pseudonyms grant individuals anonymity outside of the social context of the system environment. A defining feature of this study is our partnership with three stakeholder groups (the students, the teachers and the NUF instructors). Within the classroom pseudonymous data had meaning to individuals, however as this data moves outside of this context the data becomes anonymous. Trusted gatekeepers can have privileged access to the real identity of the pseudonyms in order to allow them to perform particular roles. In our case the teachers acted as guardians for the children and were fully aware of these identities. However, for third parties, such as NUF, the data without context becomes anonymous and can be used to evidence practice. We began our interaction with NUF under the initial premise of demonstrating impact of the Match Fit programme. However, our findings highlight that evidencing extends beyond the NUF and into the realms of school governing bodies. Teachers were required to use learning analytics data [16] to evidence the differentiation of their approach to delivering adequate physical education lessons.

The NUF instructors acknowledged their role in the safeguarding of their students. However, in collecting activity data for the entire duration of the programme we had inadvertently increased the safeguarding workload required for Match Fit instructors. The creation of data inevitably leads [10] to the use of this as evidence. However, data provides utility beyond simple metrics. For groups where there is an imperative to offer safeguarding, for instance to children, data at an excessive level of detail creates an unexpected overhead. We suggest that these systems be designed such that they record within a specific time window and offer the sufficient level of granularity to the appropriate stakeholder and nothing more.

Complicating Pseudonymity

Using this pseudonymous approach to managing one's identity in a public setting is not without complications. There are potential issues of scale that affect how these identities are managed. For example, can you maintain a pseudonym within a team of three people? Smaller sizes may well render it easier to disclose personally identifiable avatars and lose their intended purpose of control through anonymity. We recognise the complexity of this social context within the classroom our study does not provide us with a full account of the potential issues that time may bring. However, we are offering our design and deployment as a case study for future work in this area.

CONCLUSION

This paper presents the design of ThinkActive - a system to support primary school students in reflecting upon their personal activity data within the classroom using pseudonymous avatars. Our findings from a six week engagement brings to the fore, issues around handling sensitive personal data, engaging and designing for multiple stakeholder motivations, and promoting sociability and interaction between students around their personal data in the classroom. We hope to inspire work beyond this domain and into other complex and sensitive social contexts such as workplaces, shared housing, and social care environments.

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