Adam Ray Braun
Design Challenges 2017/18

Little Brother

Classroom Companion

THE BRIEF

TRADGEDY OF THE COMMONS

This project set out to answer a brief that proposed problems on two scales: the larger issue of the tragedy of the commons, and within that how these issues arise within the British education system. American ecologist Garret Hardin defines a tragedy of the commons in his 1968 essay:

"When there exist common resources, for which there is no private owner, the incentive among rational users of that resources is to exploit it to the fullest potential in order to maximise their own self gain before the resource is depleted" (Welker, 2018)

A famous example of this problem is highlighted in fishing and deforestation. Both marine life and forests are natural resources that all of us benefit from, yet because each individual exploits this resource in their own self-interest, the value is depleted, spoiling the resource for everyone else.

This problem often arises in the school system. Educated individuals benefit society as a whole, yet schools with alternative priorities often results in a society of people not receiving the learning most valuable to themselves and society. These ulterior motives often revolve around the pursuit of finances or higher grade results, rather than true quality of education.

Education's place as a tragedy of the commons is further highlighted in the brief:

"As a society we all have a stake in public education systems, and we recognise that higher levels of education track with lower incidences of crime, lower healthcare costs, higher employment rates and many other factors likely to improve conditions for everyone."

DESIGN THINKING

Because of the large and infrastructural scale of these problems, there are two methods of design thinking; speculative and policy design. Because the root of much of education's problems stems from the bureaucratic nature of a government led system, policy design holds the possibility to challenge these systems, aiming to fundamentally change the education process from within.

Speculative design's weight comes from creating provocative 'what if' scenarios. Speculative design can look at current situations and extrapolate alternative scenarios, new realities that highlight current problems and/or suggest creative solutions.

The Problem

Creativity in primary education

The British education system maintains detailed and regular analysis of its education practice across the UK, including regularly collecting and making publicly available large amounts of data that report on key factors. The reports paint an informative picture of the large scale process, making a useful starting point in understanding problems in education. One report, 'Summer Exam Entries...2016', presented results that showed an immediate problem:

"Entries for GCSEs in arts subjects have fallen by 46,000 this year compared with last... This year's loss is more than five times the size of the loss in 2015." (Dhawan, 2016, p. 5)

This quote prompted my research into what was soon identified as a major issue in primary education. A report from the University of Warwick also held similar information citing a drop in students choosing arts subjects:

"Between 2003 and 2013 there was a 50% drop in the GCSE numbers for design and technology, 23% for drama and 25% for other craft-related subjects."

These two reports clearly show a diminishing amount of students being educated in the arts, a problem that affects each student and us as a society. But to what extent is this damaging?

Studying the arts develops abilities in creativity, innovation and resilience (Cultural Learning Alliance, 2017, p. 2), features that not only make individuals more valued future employees, but also improve their personal lives. Thousands of students are not benefiting from the ability of arts subjects to foster these attributes is certainly unfortunate for each individual, but also affects our society as a whole.

If we look no further then the pure economic contribution visually creative subjects make, it is clear the professions are a cornerstone of the country, adding £76.9 billion to the economy in 2015 (Warwick Commission, 2015, p. 20).

The place of creativity is increasingly important in our daily lives, as we surround ourselves with material and digital objects, we are ingesting an increasing amount of creatively made content on an almost non-stop basis. The increasing frequency with which we consume creative content is not only why it's such a profitable part of the economy, but why it's an integral part of many of our lives, employing over 131,000 British people in 2015 (Cebr, 2017, p. 5).

This issue was highlighted by the Higher Education Policy Institute in 2017 when it released an article titled 'A crisis in the creative arts in the UK?' (Last, 2017, p.1). In this document Professor John Last of Norwich University explains the social disparity between creative and core education:

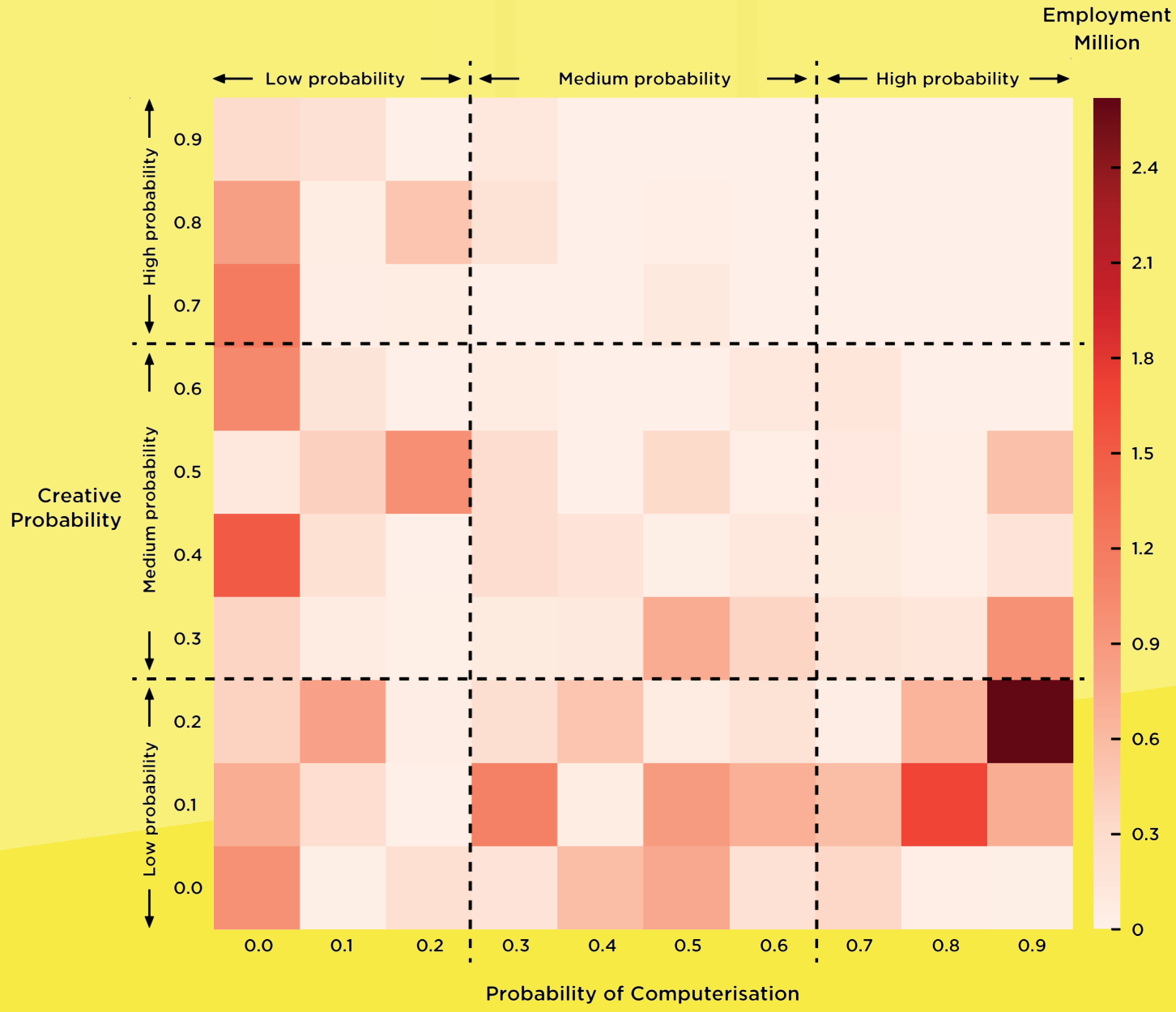
"A flawed equation dominates thinking about the economic value of education in the UK. According to this equation, improving literacy and numeracy equals economic prosperity and individual prosperity. Creating art or appreciating artistic endeavour is seen as producting a nation with an enriched cultural and social life, and a possible route to fulfilment. But there is a flaw in the logic that says to count is to be economically productive,but to create is not. To ignore the economic value of the arts and creative industries is to ignore an £84 billion annual contribution to the UK economy, 1.7 million british jobs, and a 9 per cent share of the UK's export market."

THE PROBLEM

CREATIVITY IN PIMARY EDUCATION

The lack of creative teaching is especially detrimental when considered in predictions of our future industries. As technology accelerates in its development, the automation of jobs by machines is an industrial, economic and social change that is likely to have an enormous impact in the 21st century.

The 2015 NESTA report, 'Creativity Vs Robots', clearly sets out the important role creativity plays in the coming waves of automation, defining it as one of the traits hardest achieved by artificial intelligence. As shown below (Bakhshi et al, 2015, p. 15), the report includes charts comparing the likelihood of creativity and computerisation of many jobs, clearly concluding that the least creative were the most likely to be computerised.

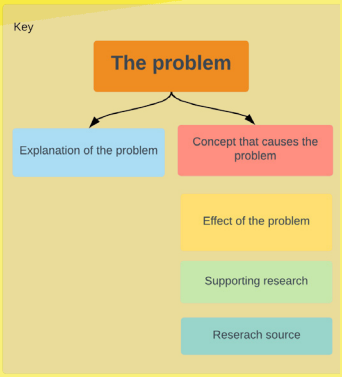


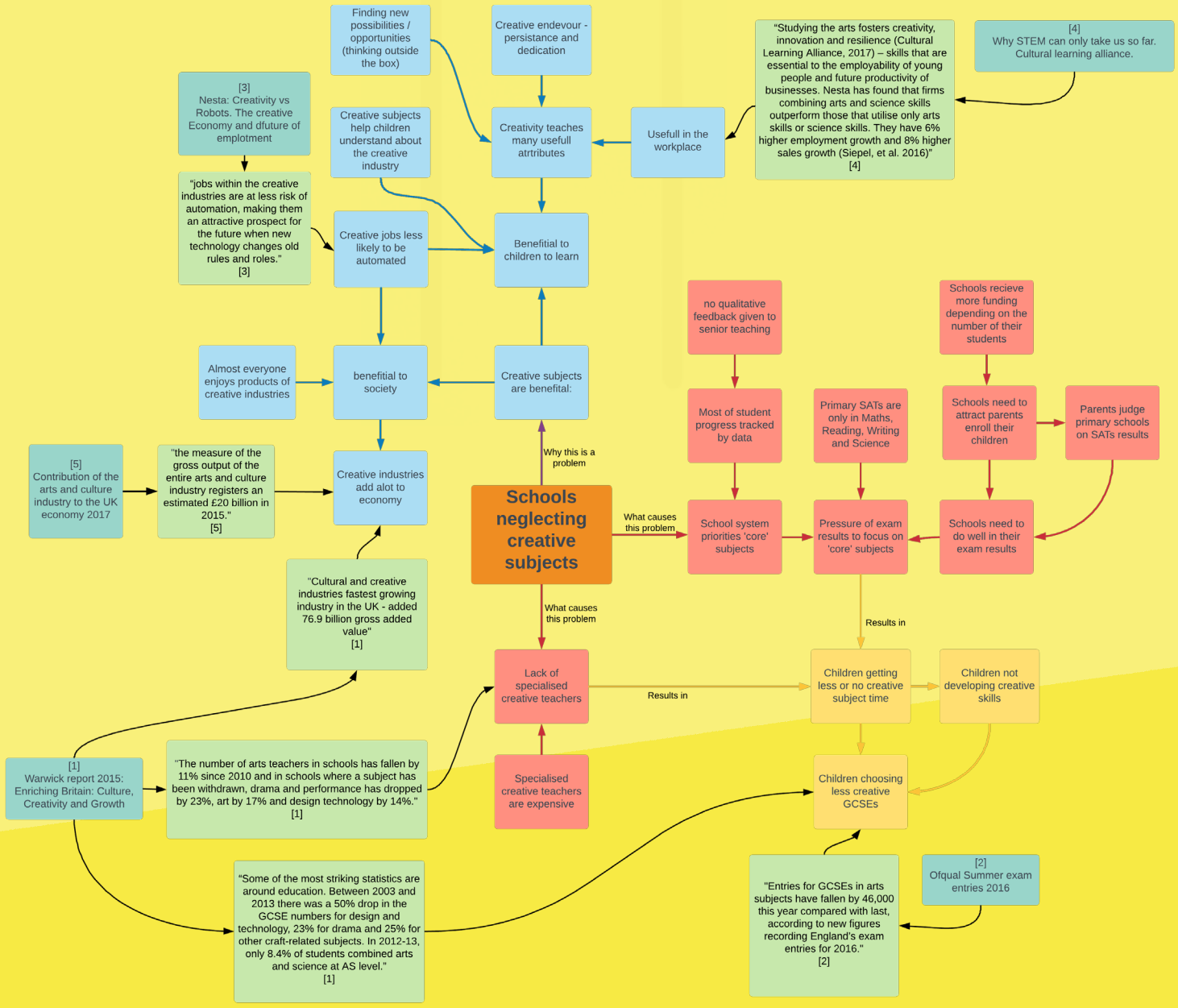
CONCEPT MAP

UNDERSTANDING THE PROBLEM

The starting point of this research was the GCSE exams results that reflect such declining creative intakes. These exams are the first exams students undertake when starting secondary level education. To understand the cause of the problem I researched the SATs exams, taken by students at the end of their primary education

Having discovered a variety of problems within the area of creative teaching in British education, I connected the problems all in a concept map to diagnose the issue at the core of these symptoms. This map helped me synthesise my research and understand the core of the issue in greater detail.





CONCEPT MAP

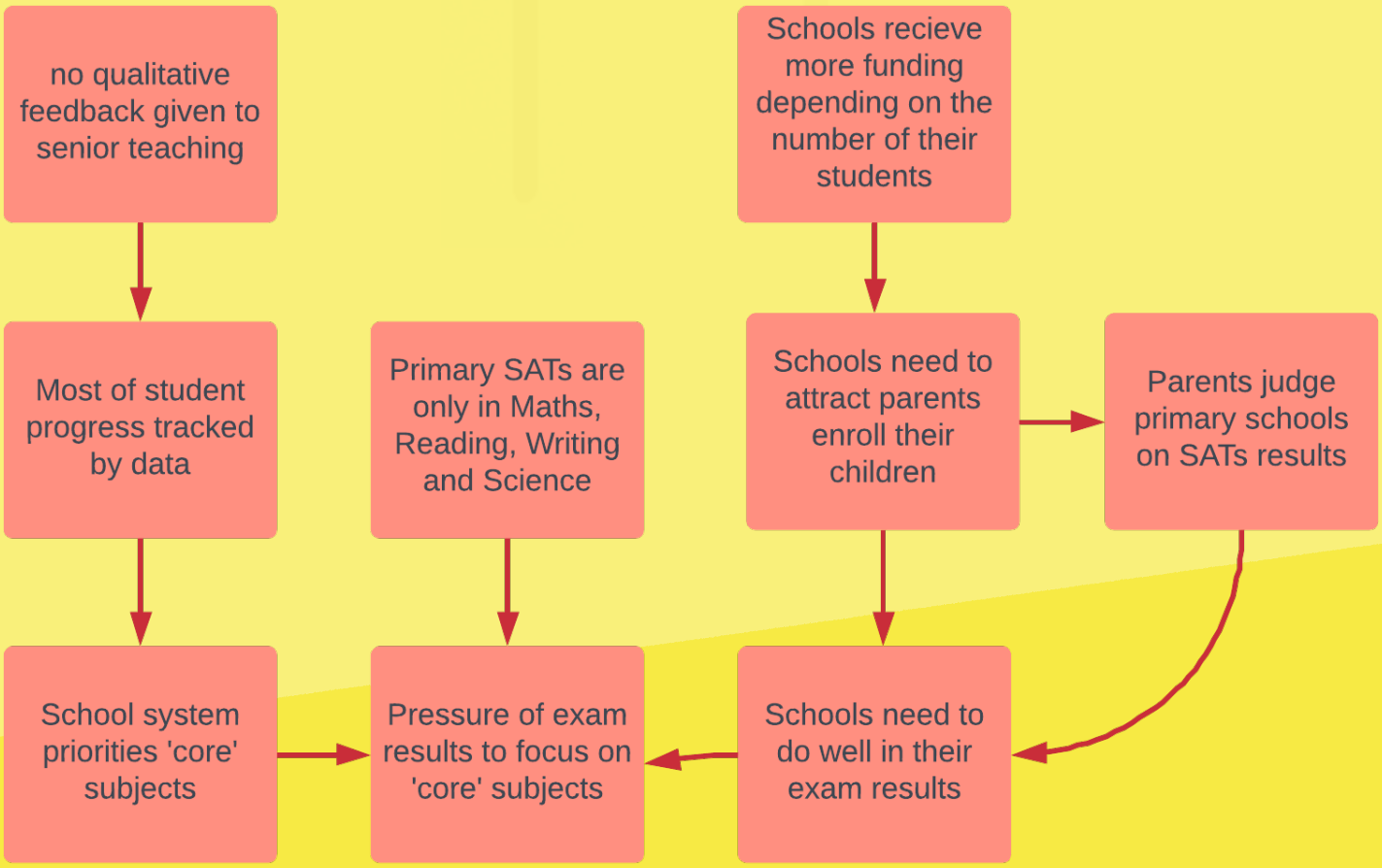
PROBLEM DETAIL

Core subjects are the four sections that are examined in the SATs: maths, reading, writing and science. Though there is undoubtedly a level of creativity in all of these subjects, it is not focussed on to the same extent as 'creative' subjects such as art, design, music and drama. The highlighted section of the concept map below shows how three main pressures convene to create the core issue.

1. **Schools need to perform well in SATs results tables in order to attract more students and by extension more funding.**
2. **The SATs only test core subjects**
3. **Core subjects create more qualitative data about students' progress, making the system easier to observe and run.**

Further synthesizing these pressures has helped clarify the particular problem I am tackling in this project:

The sidelining of creative subjects in state primary education



PRIMARY RESEARCH

ETHNOGRAPHIC METHODS

Now that the core problem has been isolated, it would normally be standard procedure to conduct first hand ethnographic research to come into contact with the problem and understand how it unfolds. Because this issue is based in Primary schools, this would involve physically being in the classroom to observe lessons. Unfortunately the bureaucracy required to organise external visitors to primary classrooms wasn't in the scope of this project, however a plan was still laid out on how research would be conducted if this project were to be taken forwards.

If secondary research has diagnosed the problem as the sidelining of creative subjects in state primary schools, then as the designer I would need to immerse myself in that setting, observing multiple steps of the teaching process. These observations should allow me to fully understand how the problem arises and manifests in primary schools. There are three main stages in the school system that would require observation:

1.) At the grass roots level of education, I would need to observe lesson time, observing and recording how a variety of core and creative subjects are taught. These observations will not only yield quantitative amounts of time spent teaching core / creative subjects, but will give me the opportunity to compare qualitative observations on the teacher's process. Analysing the difference in teaching across different subjects, teachers and student classes will let me build up a clear image of the main symptom of the problem being tackled.

2.) To gain a better understanding of the source of this problem, it would also be beneficial to sit in on the regular school faculty meetings between teachers and and administrative staff. These meetings are occasionally weekly or monthly and allow for communication between those planning the overall teaching process, and the teachers putting it into action. The meetings would not only help me understand the decision process behind the prioritisation of teaching cores subjects, but would give valuable insight into the individual's reactions when these decisions are carried out. Teaching staff are not only tuned in more than most to the importance of a creative education, but as the facilitators of learning, could be valuable individuals to work with in the later design process.

3.) At its top level, the school's administration communicates directly with the Department of Education. Though these interactions are the least regular, observing these would give a clear insight into the relationship between government curriculum and school specific teaching.

Observing these three stages in the school process over multiple occasions and preferably at multiple schools, would build up a comprehensive understanding of the problem - an understanding that requires a carefully designed solution to fit such a multifaceted issue

Primary Research

Teacher Interview

Though first hand access to schools' is out of scope for this project, externally interviewing teaching staff can still give valuable insight into the same problems. I interviewed Mandy Holland, a primary art teacher at Churchfields Primary School (Holland, interview, 2018). Mandy's position as a dedicated art teacher is rare in british schools, especially in state schools where every subject is normally taught by the same class teacher.

I conducted this interview in a quiet cafe that allowed Mandy and myself to comfortably sit and talk. To insure a free flowing conversation I recorded the whole conversation on a dictaphone for later transcribing, freeing myself of having to make notes while talking.

Mandy completely agreed with the problem of sidelined creative lessons, citing that it has been declining for years. Her school has a more progressive creative system, hiring specialists like Mandy to teach at least one hour of art a week, but Mandy claims this is more creative exposure than most other London schools she is familiar with. From Mandy's experience, she cites the year 6 SATs exams as the single largest factor in prioritising of core subjects over creative subjects. She added that even in reception (4-5 year olds) there is now an overwhelming focus on formal learning where there used to be play based learning.

Mandy explained how important good SAT results are to the schools, indicating that SATs league tables are the primary factor parents use in deciding which school to send their child to. She explained that this prioritising of core subjects often comes from the teachers themselves, pressured by a system that judges their worth by their class's SATs results.

To understand the extent of this prioritisation, I asked Mandy just how much class time the SATs require:

"Roughly two thirds of year six is spent revising previously learnt skills so that they achieve in their SATs.... After Christmas our year six children who are underachieving are invited to come into school an hour early, two or three days a week to do extra maths or extra literacy, from now until their SATs in May!"[7]

This clearly shows that teaching the SATs is so consuming it often expands outside of regular class time. The overwhelming pressure to get students exam ready is a clear cause of the lack of time found for creative subjects.

"If you're a class teacher... and you're getting judged on on your student's core subject, if you're timetabled in for an art lesson but they haven't actually quite got adverbials yet then art gets sidelined."[7]

CURRENT SOLUTIONS

MY CREATIVE SCHOOL

Mandy Holland also explained that that her school has become involved in a program called 'My Creative School' funded by the Paul Hamlyn Foundation. This is a three year program that aims to investigate how 'schools and arts organisations work together to develop creative activity' (Woodward, 2016). Three schools in three seperate London boroughs were each allocated funding and a creative practitioner for collaboration, with the aim of engaging teachers to be more creative in their practice.

This is an interesting example of a current attempt to solve the problem of creativity in primary schools. The program focuses on a particular angle of solution, attempting to solve the problem at the classroom teacher level, rather than changing larger scale policies. Mandy explained that this program encourages proactivity in teachers by organising meetings between the 9 schools, allowing collaboration between teachers and practitioners in their methods.

When this program was run for the first time last year (2016/2017), the report claimed overall success, indicating the ways in which schools had decided to incorporate further creativity in their curriculums:

"Around half the schools have demonstrated a clear strategic direction for the future demonstration of practice... In the other six schools, teachers have expressed their intentions to develop work and embed it in their practice."(Heaney, 2017, p.3)

The success of this program in challenging teachers to include creativity is impressive, this method clearly worked in improving the school's priorities, and in individual pupil's abilities:

"New approaches have impacted significantly on pupils' skills development, with evidence of increased confidence and ability to question and improved levels of speaking and listening in several case studies. This includes significant gains for focus group pupils in related criteria. These gains are reflected in corroborative data from schools' data tracking systems, although more analysis is needed to generate more exact data and identify causal links between MCS (My Creative School) inputs and gains in achievement in core subjects."(Heaney, 2017, p.2)

My Creative School is a useful example of the success that can be achieved with well thought out interactions, even in a relatively small quantity. Though this has so far proven its use, I'm curious as to how well it would work on when scaled up. In 2017 there were 16,786 primary schools in England alone (Department of Education, 2017, p.4), My Creative School has shown local success, but would it still be feasible to fix the wider problem?

THE SOLUTION

IDEATION

Within the realm of educational tradgedy of the commons, I have now isolated the particular problem I will be attempting to solve:

The sidelining of creative subjects in state Primary schools to focus on SATs exams

My Creative School has highlighted a current method of tackling this problem, showing local success, but with potential limitations fixing the problem at a national scale. One solution to the larger problem would be to design changes to the SATs policy, including creative subjects alongside core subjects being examined. This solution would place creativity as an equivelent priority in schools, ensuring that it recieved the same amount of teaching time. Though this would guarantee the teaching of creative subjects, it would add to the already mounting pressure teachers are under.

This is not an ideal solution as the interview with Mandy has already shown the compramises already being made in schools to ensure success in SATs results. To design around this would potentially involve proposing a whole new system of examination (or lack thereof), a task that seems required for this country, yet isn't in the scope of this project.

Critical / speculative design appears to be the best approach, proposing an alternative scenario could rasie awareness of the issue by provoking thoughts about why our current situation exists.

Little Brother

Ideation

My proposed solution to the problem is Little Brother, a robot that sits in every classroom observing teaching to ensure time isn't being wasted on creative teaching when it could be used to teach SATs subjects. This speculative design criticizes our current prioritisation of core subjects in primary education, a product for a not too distant reality where government and school faculties are fully devoted to a system that focuses on academic exam results over creativity.

Little Brother's name is a reference to Big Brother, the figurehead of the totalitarian state of surveillance in George Orwell's famous dystopian novel, 1984 [11]. Like 1984, Little brother uses themes of total government involvement to provoke questions of our current surveillance-heavy situation.

Little Brother is a small tabletop robot that sits in every classroom, observing what is taught. Artificial intelligence analyses visual and audio inputs to recognise when the class strays away from the curriculum and starts teaching creativity. When Little Brother detects valuable class time being wasted on creative subjects it immediately notifies the school faculty so that they can correct the teacher. If these discrepancies are continually detected in a school, the Department of Education is notified of a more serious long term problem.

Camera & microphone capture audio and video of classroom activities

Each Little Brother sends detected creativity data to a central government run server

Server alerts head-teacher if creativity is detected in a classroom.

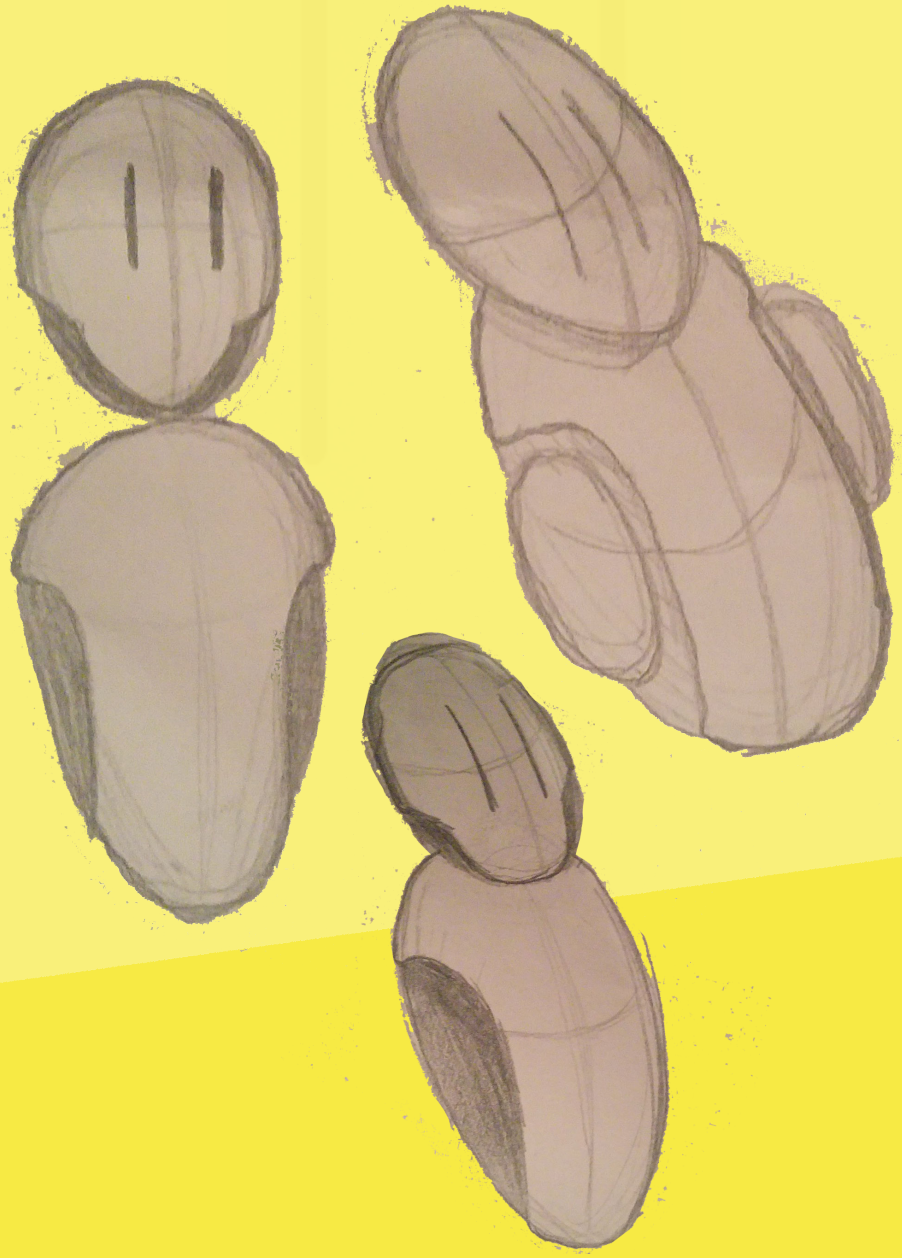
PROTOTYPING

FORM DEVELOPMENT

The form of Little Brother needed to fulfill two technical features; the ability to move the camera / microphone for multiple viewpoints around the classroom, and internal space to house all of the electronics.

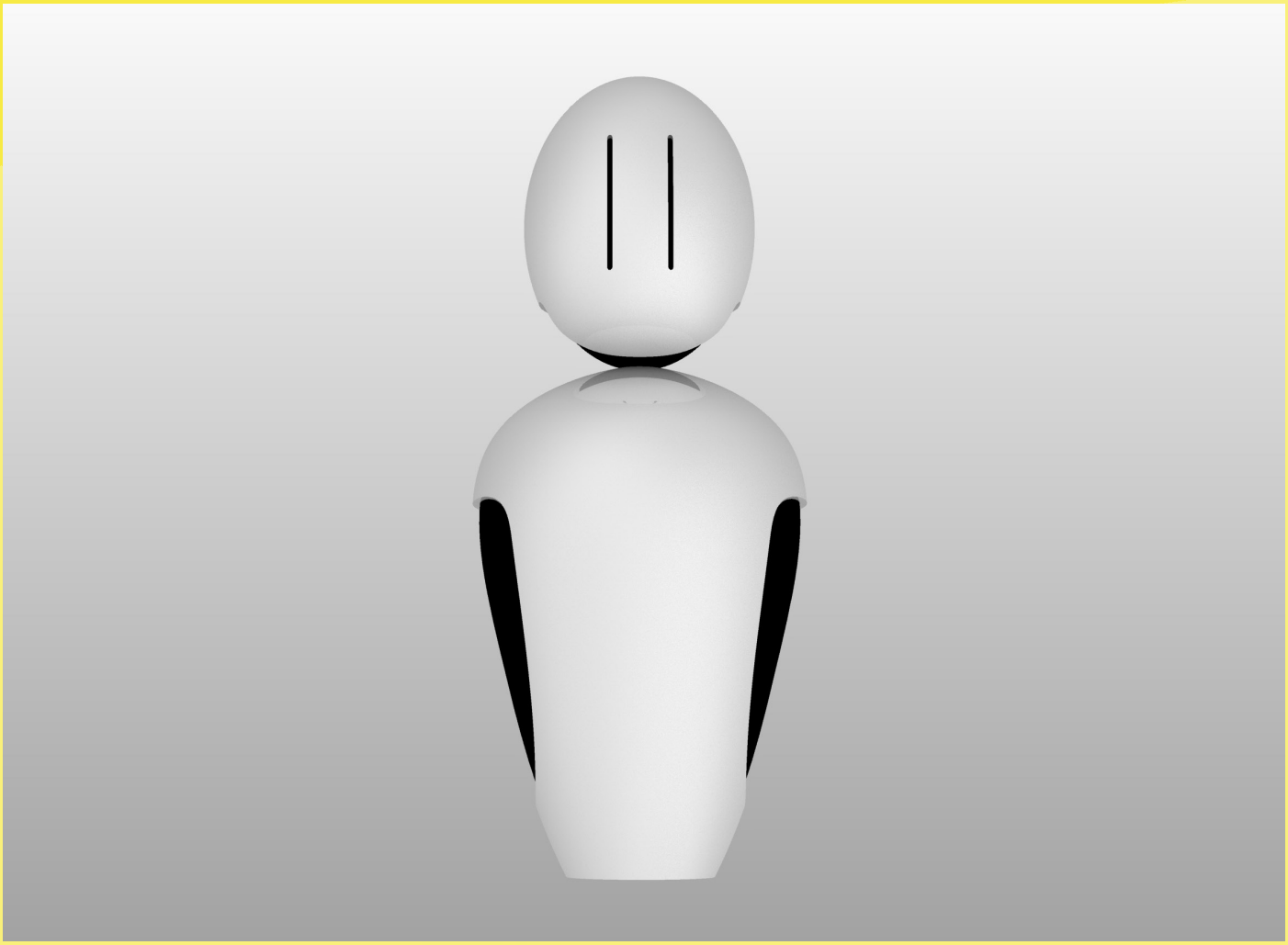
I wanted the form to be somewhat unsettling / creepy, highlighting the unpleasant nature of constant surveillance in classrooms. To achieve this I roughed out multiple variations of vaguely human body shapes, trying to use the uncanny valley to make Little Brother look visually disconcerting.

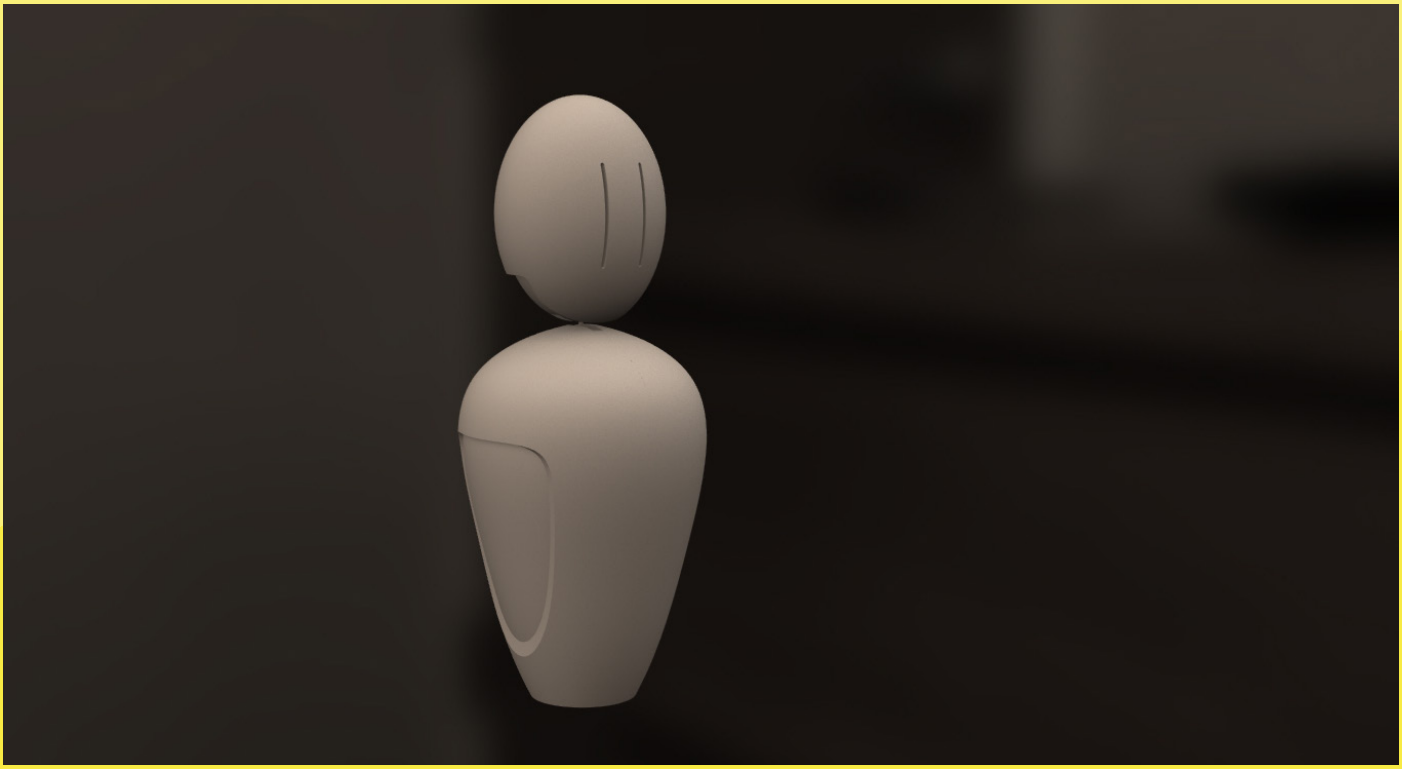
In the chosen design, Little Brother's two horizontal stripe 'eyes' create a face that is recognizable but unreadable. This combined with a lack of any visual / audio outputs from Little Brother add to its creepy nature, constantly watching but not expressing any information to the class.



3D Model

Form development



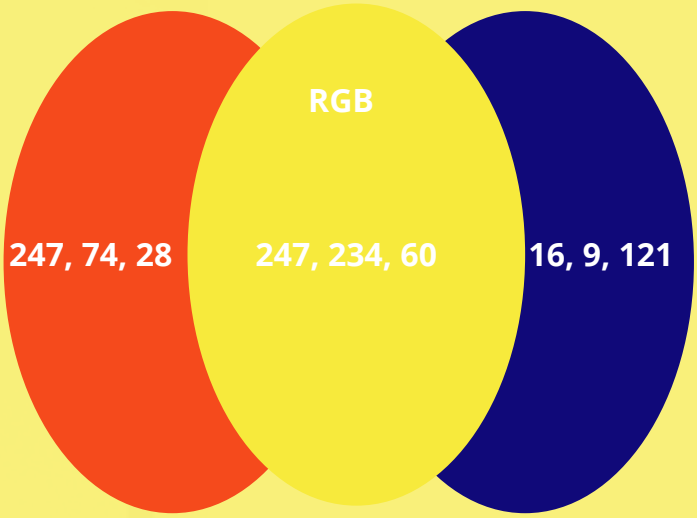


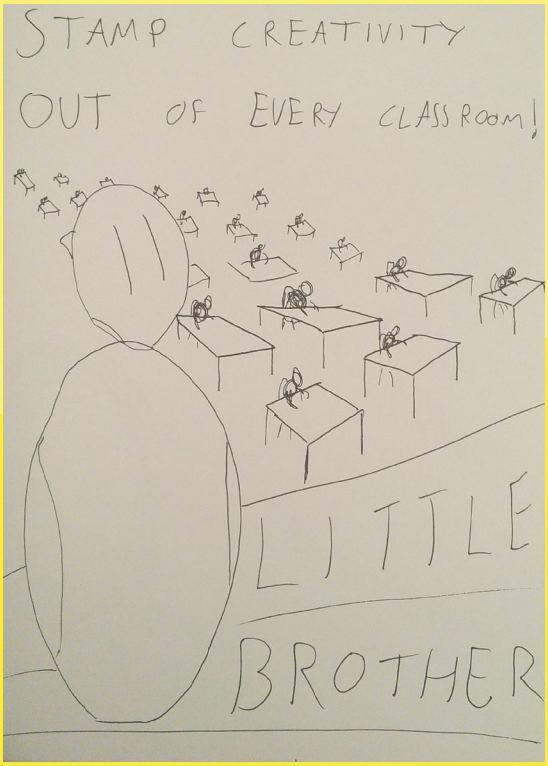
Poster Design

I made a poster to display Little Brother as an idea that is subtly unsettling. Because this project is speculating on an extremely bleak outlook of modern society, I looked for inspiration from more playful graphics to ensure the project wasn't overwhelmed with dystopian predictions. I found inspiration in mid century American packaging, bold graphical looks that were so vibrant and playful they almost became unsettling.

My main inspiration came from a PAL bubble gum sticker displayed on gumball machines from the 1950s. Because this layout already contained an uncanny child I thought it would transfer well to displaying Little Brother.

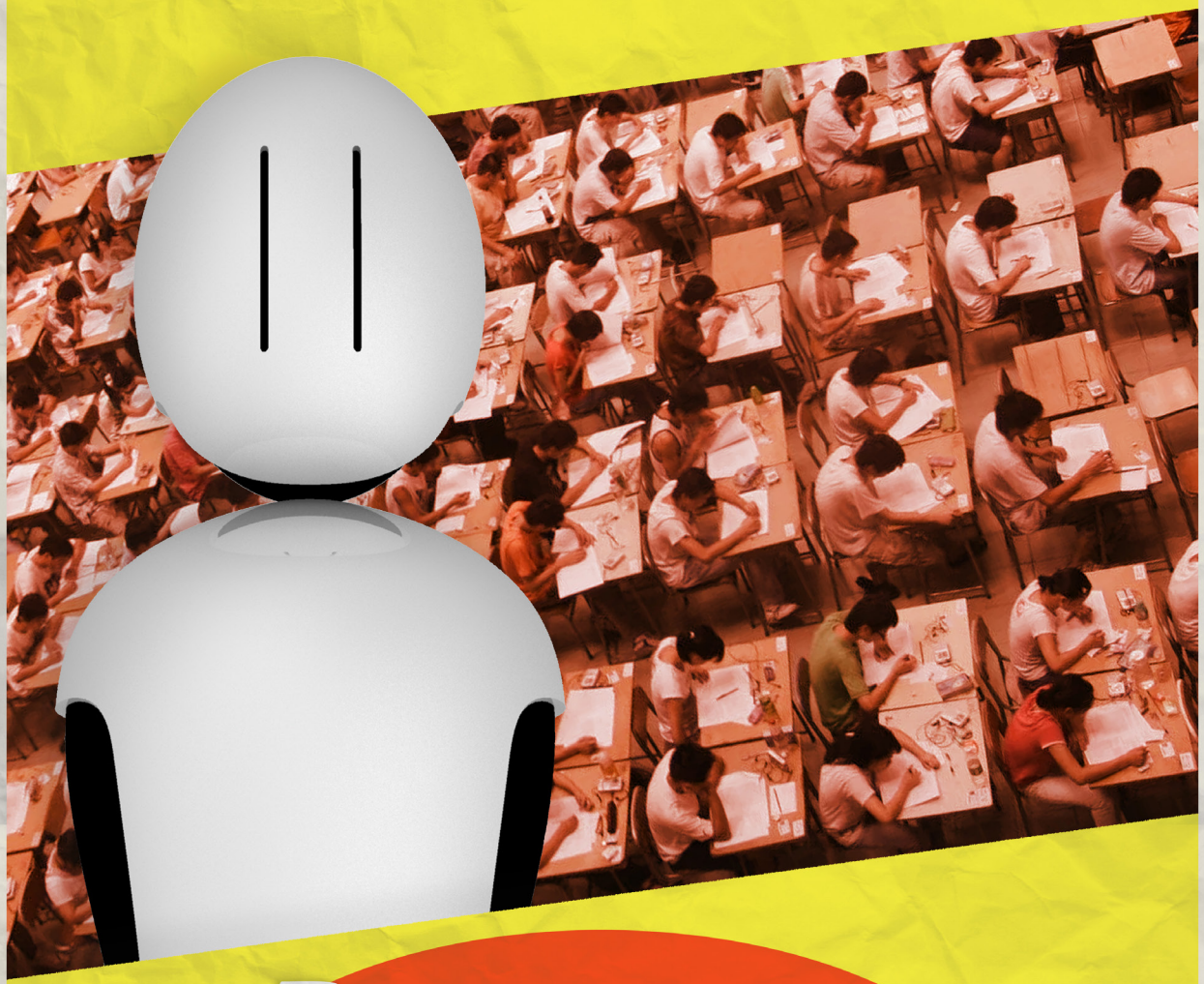
The poster was designed in Photoshop using a hall full of students as a coloured background to a rendered portrait of Little Brother. I included the propaganda-like tagline 'Stamp out creativity in every classroom', to highlight the governmental use of Little Brother for control.





POSTER

STAMP CREATIVITIY OUT OF EVERY CLASSROOM



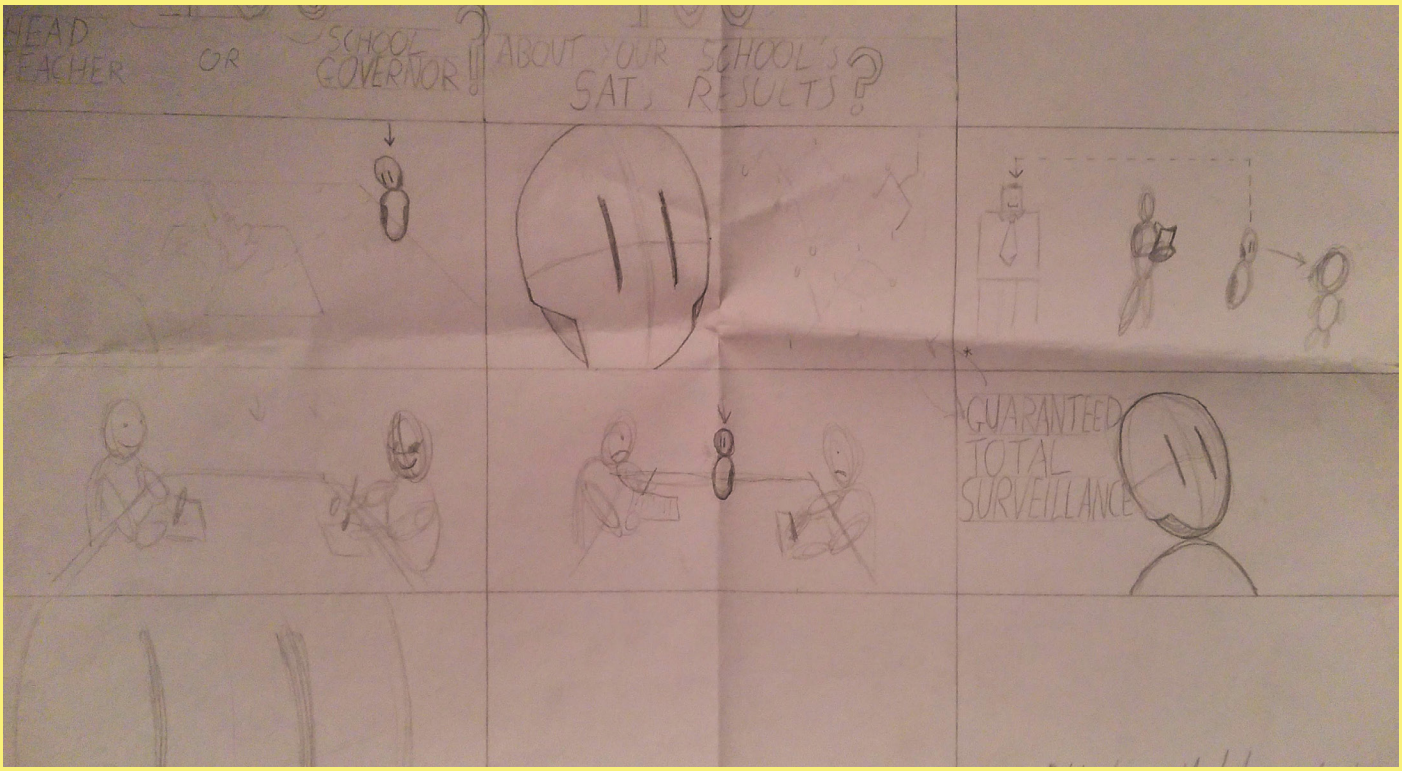
LITTLE BROTHER

CLASSROOM COMPANION

FILM MAKING

STORYBOARDING

A short film was produced to explain the concept and execution of Little Brother with speculative design that revolves around provoking imagination. Film was an incredibly useful tool to explore how the design would function in situ. I scoped a film in the style of an infomercial targeted at headteachers or the school faculty. Instead of explaining the speculative nature of the piece, the film places the user in the scenario, faced with the absurdities of a product that would minimise creativity in education.
The absurdity is an important feature. It invites the viewer to form an opinion against this hypothetical situation before they compare it to the reality of our current school system. I created a storyboard to rough out the film's layout, starting with inviting in headteachers as users before advertising Little Brother as a product that will end their problem of time wasted on creativity in the classroom. The full film can be viewed on a private vimeo here: https://vimeo.com/261428239 (with 'ravensbourne' as the password.



FEASIBILITY

OVERALL

The impact of Little Brother as a speculative piece is largely based on its feasibility. The believable nature of the technology and implementation allows the viewers' imagination to focus on the ideological problems in our education system, rather than questionning the possibility of the product.

Little brother has been designed to function , be manufactured and distributed all with commonly available modern processes. The insinuation that Little Brother will be widely used in schools across the country adds to its intimidation. This larger scale of surveillence instills a sense of hopelessness if it spawns from a seemingly unstoppable organisation such as a country's government. However large scale adoption relies on its affordability in all schools. The following feasibility plans lay out methods of manufacturing while aiming to keep the price at an affordable level.

FEASIBILITY

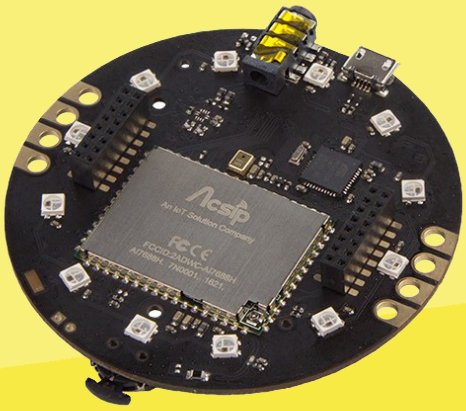
HARDWARE

The hardware required for little brother can be split into 6 main sections:

1.) Physical movement - Little brother needs to be able to pan and tilt its head to look around the room, both to achieve multiple angles of detection, and to add to the uncanny feeling of seeing a robot actu-vely watching the user. This movement can be achieved with a combination of two 5v servo motors inside a pan / tilt bracket.

2.) Image capturing - Little brother will need a camera to visually understand the classroom activities, which is be achieved with a Balser ace Series camera. This is a small camera sensor recommended for computer vision because of its ability to output a variety of high resolution formats straight to image processing.

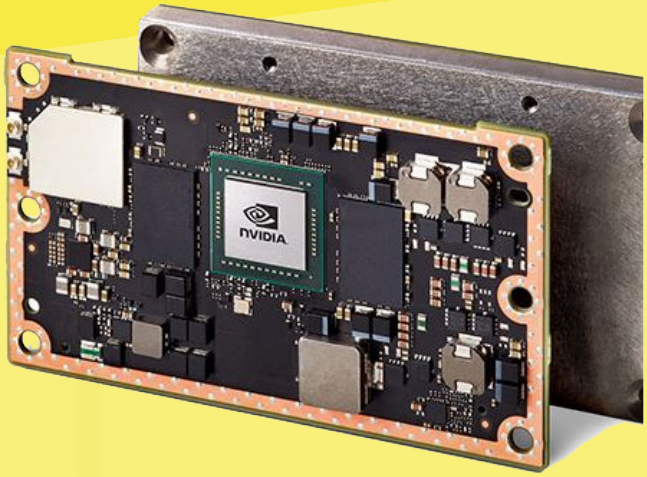
3.) Audio capturing - Recording the spoken conversation in the classroom will be one of the easiest methods Little Brother will use to determine the subject matter and therefor creativity. The ReSpeaker Core is a microphone module that includes a speech recognition engine. Seperating the audio precessing to a seperate unit frees up processing power for the rest of the analysis.



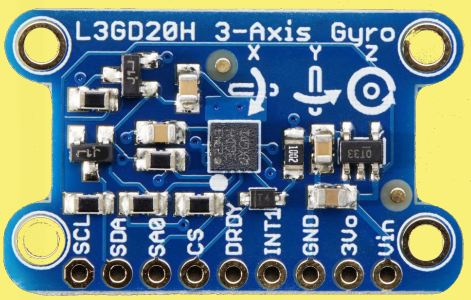
FEASIBILITY

HARDWARE

4.) Processing - Little brother will need a central processor to control the inputting and analysis of said data and internet communication to pool information and notify the user. The Nvidia Jetson TX2 is a lightwieght processor with the specifications to run hardware intensive deep learning sofware.



5.) Environmental sensors - Little brother will need to detect its orientation and local temperature to ensure that it is operating in idea conditions. This awareness of the environment will also help prevent little brother being hidden / fooled by uncooperative teachers. The L3GD20H and the TMP36 will record gyroscopic and temperature information respectively.



6.) Power supply - Little brother will need a constant power supply to operate. To avoid Little Brother being superceded by mobile teaching using portable power, Little Brother could use a powerful 7v Lipo Battery. This battery can be charged with a Qi wireless charger. Little Brother can be placed on its charging matt in the classroom to be ready to roam when needed.

Feasibility

Software

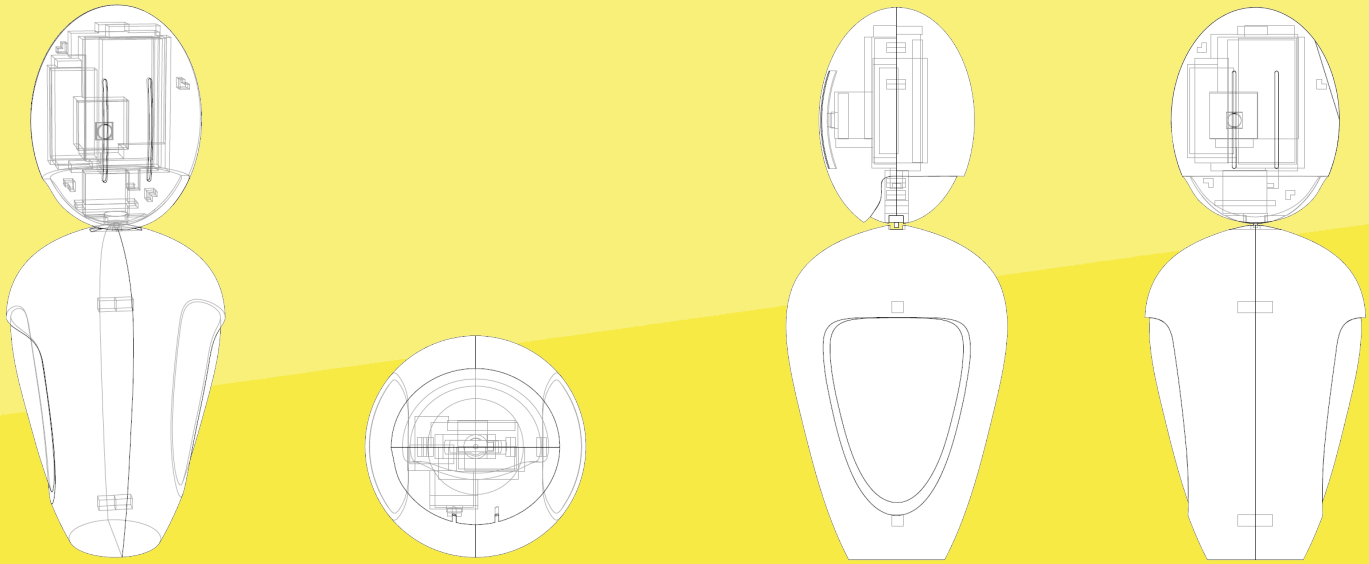
In the physical form of Little Brother, the required software breaks down into two main functions:
1.) Generic computer vision and audio voice recognition - Little Brother will detect overall changes such as lessons beginning, student presence and subject matter. The voice recognition will be executed within the ReSpeaker Core, freeing up processing for general tasks. The image analysis will be run on OpenCV, a professional standard open source library for computer vision.
2.) Internet communication - to send recorded information back to central servers for analysis

The complex process of taking the recorded information and deciding on its creative content will be executed server side by neural networks. This server side operation is more convenient for the hardware requirements for this machine learning. The servers will collate collected information from Little Brothers in schools around the UK, constantly updating its data set to improve the accuracy of its creative diagnosis.

Manufacturing

Little Brother's body will mainly be comprised of an injection molded plastic shell. The head and body will be manufactured in two halves, each half with custom internal spacings to house electronics and to mechanically lock into the other sections.

The electrical components will be assembled in Little Brother's head, saving the need for wireless communication between the head and body sections. The listed components will all connect via a custom design PCB.



PROTOTYPING

FUNCTIONALITY

To manifest this design into a tangible product, I prototyped some core elements of Little Brother to further develop the design and prove its feasibility. I chose the three physical elements of Little Brother that I considered the most essential to its function:

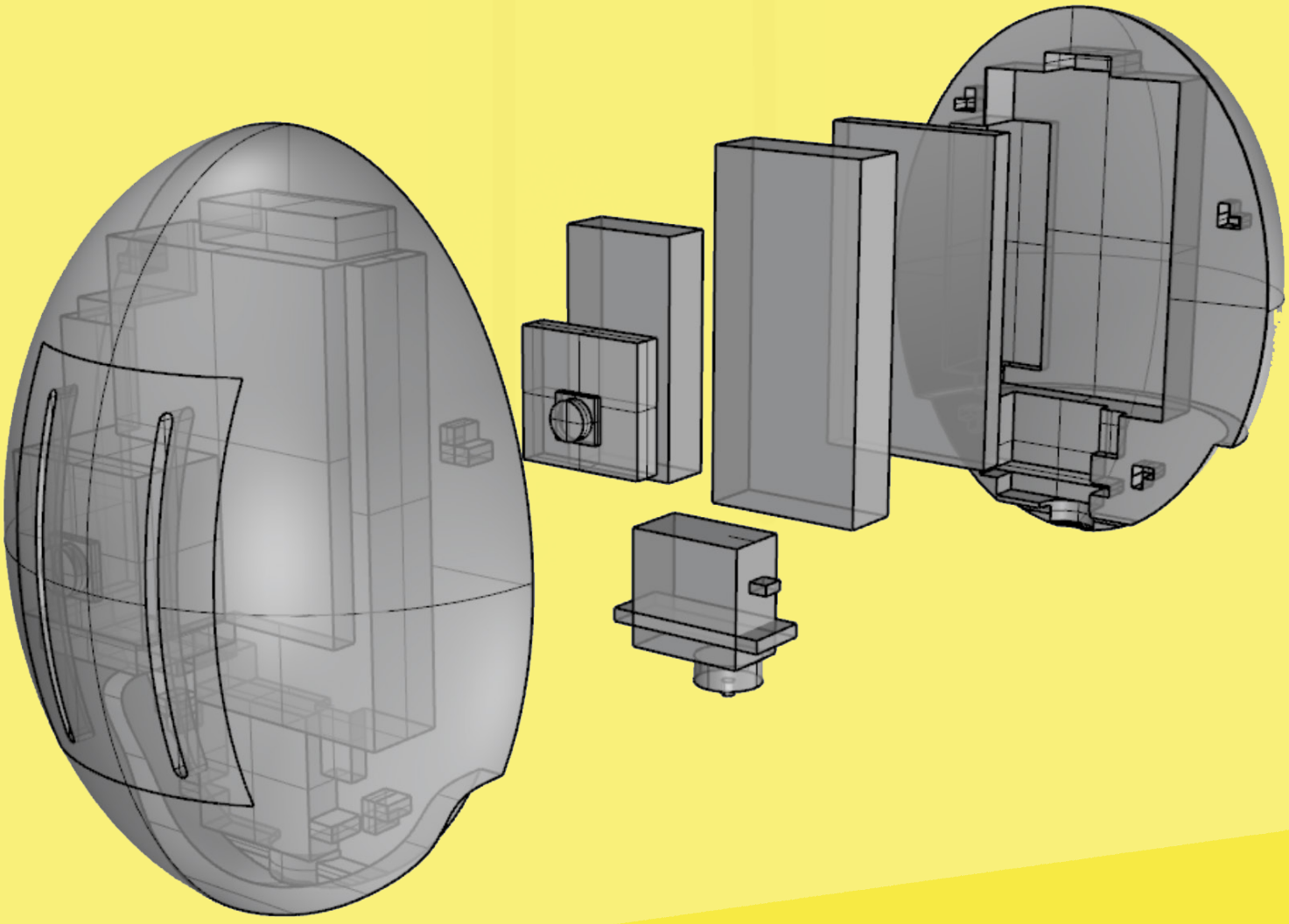
1.) The size and shape of its phyiscal form
2.) The user interface manually controlling Little Brother
3.) The rotation of Little Brother's head.

These elements combined to provided a prototype most representative of Little Brother's final design within the time and financial scope of this project.

PROTOTYPING

FORM

After designing the initial exterior 3d model of Little Brother in Rhinoceros, I adapted the design for 3D printing, including internal compartments in Little Brother's head to house all of the electronics. Because the rotation between the head and body connects with a servo motor, there was no way to run cables discretely between the two bodily sections. With the camera situated in Little Brother's 'eye', it then made sense to house all of the components in the head section, leaving the body section solid to even out weight distribtuion.



PROTOTYPING

USER INTERFACE

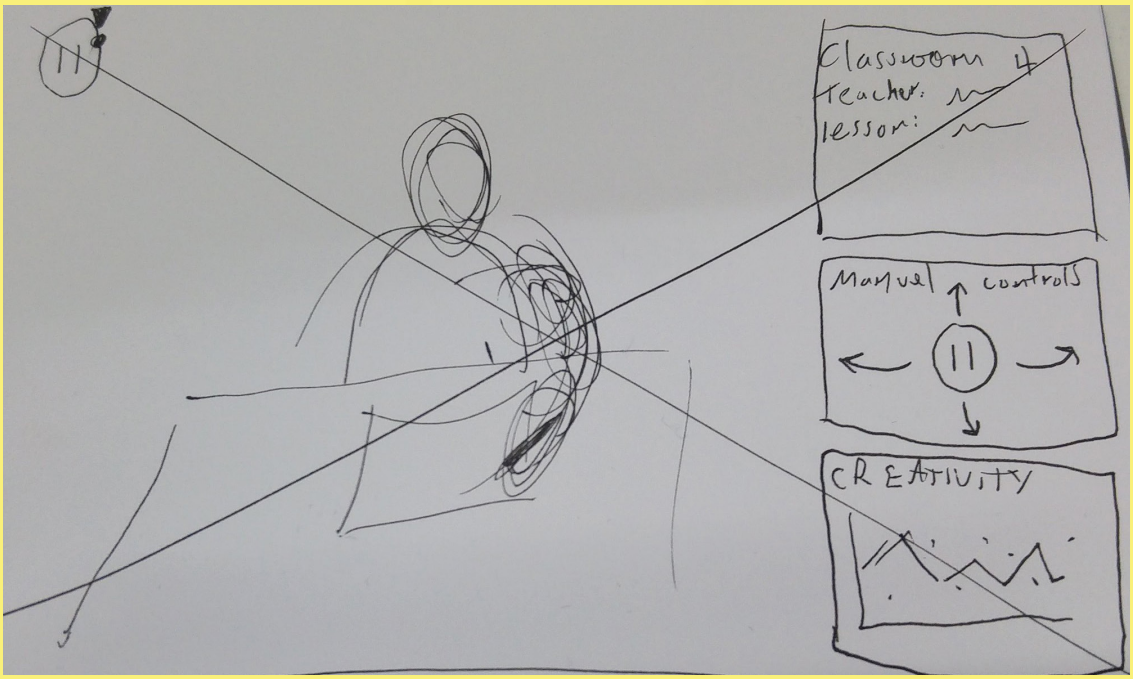
The footage from the Pi's camera is used to mock up a user interface for a heateacher / faculty member manually observing / controlling Little Brother. This interface consisted of a website run from my laptop, iframe-ing in the streamed footage as the site's background, underneath premade visuals. Though this GUI wasn't interactive, it was useful to prototype how these interactions with Little Brother would take place, developing how Little Brother portrays its use to the headteacher users.

USER TESTING

USER INTERFACE

In designing the interface, I presented my initial sketches to a five different students within Ravensbourne, none of whom had any prior knowledge of the project. After explaining Little Brother's purpose, I showed my paper interface, asking each participant to explain where they would be most likely to click and why.

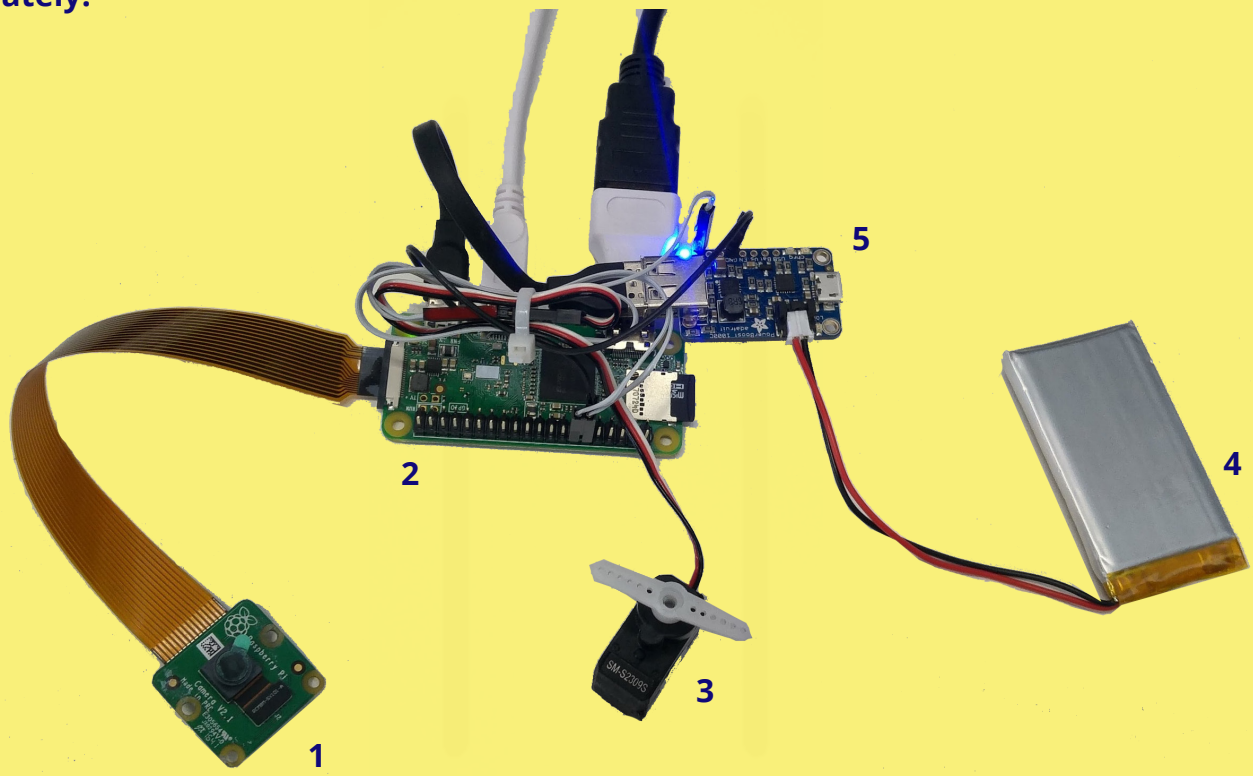
I encouraged the participants to roleplay as headteachers, on the look out for what they deem is behaviour unsuitable for classroom activity. This helped draw out suggestions for how the interface would be better designed. Although each student responded with individual feedback, the majority response was that the focus of the interface should be the camera's imagery - 4 / 5 participents suggested making the footage larger in comparison to the GUI, a suggestion I took on board when making the final version.



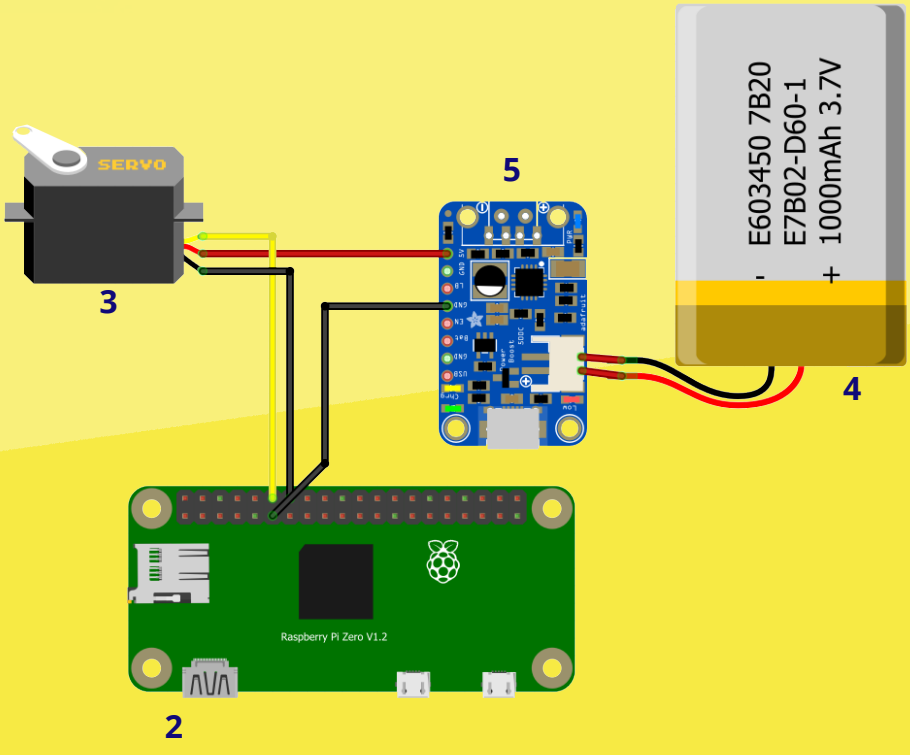
PROTOTYPING

HARDWARE

To prototype the decided functionality, I used a Raspberry Pi ZeroW (2) as a central processor. This then controlled both the movements of the servo motor (3) and the streaming of footage from a Raspberry Pi camera module(1). Because of the kickback servos product, the servo could cause the Pi to reboot unexpecedly, this was fixed by using an external power source, an adafruit powerboost 1000c (5). The module took power from a 1200mAh 3.7v Lipo battery (4) and powered the Pi via USB and the servo seperately.



This fritzing diagram shows the circuit layout of the hardware, with the exceptions of the Pi camera which is connnected straight to the Pi zero, and the micro USB cable, that charges the Pi from the powerboost 1000c.



PROTOTYPING

SOFTWARE

The Pi runs code taken straight from the Pi camera documentation 4.10 - Web streaming. This script constantly takes pictures with the camera and uploads them to a simple server hosted on the pi.

The script controlling the PWM movements of the servo motor is adapted from Adafruit's Raspberry Pi servo tutorial. Both of these scripts are relatively simple and function well in parallel.

The streamed footage for the interface was sent to the :8000 local port of the Raspberry Pi. When the Pi and laptop are connected to the same internet router, this allows my laptop HTML site to iframe in the Pi's streamed footage as a background. The overlaid graphics were built in HTML and CSS, allowing for rapid adjustments of their visual layout while the interface was being built. Recorded progress of the software development can be viewed on the Github repository at:

https://github.com/AdamRayBraun/Design-Challanges/commits/master

PROTOTYPING

Final Prototype

This prototype succeeded in demonstrating just how feasable the design is, demonstrating a range of functionality from components and processes far inferior to those used in Little Brother's manufacture. The combination of functionality housed in a scale form very quickly paints a picture of the real object in the viewer's mind, helping to focus the speculative concept behind a now tangible design.

One of the largest limitations faced in this prototype was the ability for the Raspberry Pi to access the internet from within Ravensbourne. For the Pi to laptop streaming to work, both machines needed to be connected to the same system, which proved most difficult in allowing a Raspberry Pi to be whitelisted on the internal IT system. This eventually resulted in the unfortunate compromise of running an ethernet cable to the Pi in Little Brother's head resulting in an external wire to Little Brother that distracts from the form and negates the efforts put into designing the electronics to be fully enclosed.

Moving Forward

Overall this project has highlighted a key problem in British education, researching first and second hand sources to isolate the issue of sidelined creative teaching in primary education. Methods of speculative design have been used to propose Little Brother, an ironic design that highlights this issue in our society by propsing a use of technology to futher increase the problem.

By partially prototyping this design, I have learnt just how feasible Little Brother would be to produce, understanding that a lot of the power in speculation stems from its possibility of production.

To take this project forward, my first step would be to arrange ethnographic observations in British schools. Not only would that provide evidence based research for Little Brother, but by testing Little Brother in classrooms, far richer qualitative impressions could be understood by teachers, students and parents alike.

BIBLIOGRAPHY

Welker, Jason (2018) *The tragedy of the commons as a market failure* Available at : http://econclassroom.com/?p=2945 (Accessed 23.3.18)

Dhawan, V (2016) *Summer exam entries: GCSEs, Level 1/2 certificates, AS and A levels in England: Provisional Figures April 2016*, Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/536380/Summer-2016-Exam-entries-GCSEs-Level-1-2-Certificates-AS-and-A-levels-in-England.pdf

Warwick Commission. (2015) *Enriching Britain: Culture, Creativity and Growth*. Available at: https://warwick.ac.uk/research/warwickcommission/futureculture/finalreport/warwick_commission_final_report.pdf (Accessed 23.3.18)

Cultural Learning Alliance (2017) *STEAM Why STEM can only take us so far* Available at: https://culturallearningalliance.org.uk/wp-content/uploads/2017/10/CD405-CLA-STEAM-Briefing-Teachers-Notes-08.pdf (Accessed 23.3.18)

Cebr (2017) *Contribution of the arts and culture industry to the UK economy* Available at: http://www.artscouncil.org.uk/sites/default/files/download-file/Contribution_arts_culture_industry_UK_economy.pdf (Accessed 23.3.18)

Last, John (2017) *A crisis in the creative arts in the UK?* Available at: http://www.hepi.ac.uk/wp-content/uploads/2017/09/A-crisis-in-the-creative-arts-in-the-UK-EMBARGOED-UNTIL-7th-SEPTEMBER-2017.pdf (Accessed 23.3.18)

Bakhshi, H, Frey, C, B, Osborne, M (2015) *Creativity Vs Robots* Available at: https://www.nesta.org.uk/sites/default/files/creativity_vs._robots_wv.pdf (Accessed at: 23.3.18)

Holland, Mandy (2018) Specialist Art teacher at Churchfields primary school

Woodward, S (2016) *AND secures Paul Hamlyn funding for new creative schools programme* Available at: https://www.anewdirection.org.uk/blog/a-new-direction-secures-300000-from-paul-hamlyn-foundation-for-my-creative-school-programme (Accessed at 23.3.18)

Heaney, M (2017) *My Creative School Evaluation* Available at: https://www.anewdirection.org.uk/asset/3324 (Accessed 23.3.18)

Department for Education (2017) *Schools, pupils and their characteristics: January 2017* Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/650547/SFR28_2017_Main_Text.pdf (Accessed 23.3.18)

Orwell, George (1949) *Nineteen Eighty-Four*, London: Harvill Secker