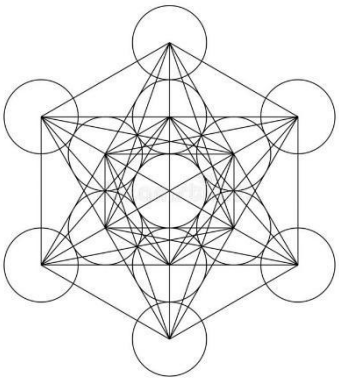
The Magic of Numbers

A Curiosity-Driven Approach to Levelling Up Education

HMC EdTech Testbed no. 7. Final draft, Howard Hotson 16/03/2022



Introduction

This document outlines another component of an interlocking set of DiSc Lab pilot projects which bring together academic expertise from across the four Divisions of the University, materials from across the full range of GLAM institutions, and technical expertise from in and outside the University to pursue a series of inter-related educational objectives.

An experiment in curiosity-driven learning. This project aims to help level up educational resources, address the Access agenda, and demonstrate the value of the Humanities by linking material on Cabinet designed for GCSE and A-level students to material created for Oxford undergraduates. But this shared goal is pursued in a different way than the complementary testbed, 'The Medicine Cabinet'.

- 'The Medicine Cabinet' will foster *examination-driven learning* by tying the materials on Cabinet to a specific GCSE-level curriculum. It will therefore use curated pathways, will test its capacity to meet the 'survival needs' of teachers in the first instance (and students in the classroom in the second), and will develop a business plan based on partnership with commercial textbook publishers.
- 'The Magic of Numbers' aims to stimulate *curiosity-driven learning* by using one of the Harry Potter films as a 'hook' to attract young people's attention. It therefore uses more flexible, user-created pathways, will test its capacity to meet the 'thriving needs' of students in their free time, and will develop a business plan based on philanthropy.

Dumbledore's Office as starting point for this experiment. Albus Dumbledore is portrayed as the greatest wizard of his age. His office is stocked with apparatus he uses to perform his magic, further examples of which are found in his lecture hall and elsewhere throughout Hogwarts. The striking thing is that most of this equipment is derived from mathematical and scientific instruments from the late Middle Ages and Renaissance.

The magic of numbers. In this period, 'natural magic' was understood as the capacity to perform feats which appeared supernatural to the unlearned because they did not

understand the natural processes on which they were based. And the key to understanding many of these natural processes was mathematics. Dumbledore's Office therefore provides an excellent means of introducing students, who may be bored or intimidated by mathematics as traditionally taught, to the 'magic of numbers'.

Oxford's museums are an unrivalled source of relevant material for this experiment**.** The History of Science Museum houses the best collection of late Medieval and Renaissance mathematical and scientific instruments in the world. Further relevant material can be found in the Pitt-Rivers, the Ashmolean, the Bates Collection of Musical Instruments, the Natural History Museum, and of course the Bodleian Library.

Relevant academic expertise is abundant. The curators of the History of Science Museum – Silke Ackermann, Stephen Johnston, and for keeper emeritus, Jim Bennett – are world-class authorities on the instruments in their collections. The Professor of the History of Science, Rob Iliffe, also presides over a Centre for the History of Science, Medicine, and Technology, which collects an enormous amount of further expertise. In addition to the curators of these wonderful collections and a host of scholars who work with them, Oxford also hosts the Simonyi Professor for the Public Understanding of Science, Professor Marcus du Sautoy. Together with the close association of the city and the University with the series, these assets make Oxford a natural place to undertake this experiment.

This test bed proposal is supported by the pump-priming funding of the Oxford-Singapore Human-Machine Collaboration Programme (HMC) – Innovation Pillar – Test Bed Portfolio. It is utilising the innovation ecosystem development budget line which supports pilots, test beds, proof-of-concepts in collaborative platform development. The test bed enables cloud-based data lake establishment and cross-departmental/cross-divisional, Oxford lab-driven research collaborations. The funding for this test bed will be transferred from the MPLS OX-SG HMC holding pot to the History Faculty (£25,000 for the 15 February 2022 – 31 May 2022 delivery period).

Motivation

Anticipating and meeting new user expectations

Understanding the impact of digital technology on educational content users is the key to identifying ways our organisation needs to transform to meet those evolved expectations. The significant ways most customer expectations have already shifted, regardless of age or learning interest, can be tracked back to the original brands (e.g. on demand: Amazon; real time: Google; personal: Netflix; local: Uber; effortless: Apple (Herbert, 2017, p. 32). As a result of these changes, we all expect interactions with every organisation to be more tailored to our individual preferences because the technology enables it so well. Features like personalisation for individuals and localizations are not only possible, but also increasingly necessary.

Back to basics: curiosity as the driver of lifelong learning

National educational systems such as that of the UK have fallen into the trap of 'teaching to the test'. The goal of the school, and therefore of the teacher, is to raise educational standards. Educational standards are equated with examination results. And examination results are determined by highly mechanistic assessment regimes which reduce the whole educational process to the business of mastering the 'right formula' for answering a specific kind of question in a pre-determined way. As a

result, education is virtually equated – in the minds of schools, teachers, and therefore students – with examination preparation. This approach deviates radically from the principle of most traditional educational theory and practice: the earlier idea was that the role of the good teacher was to ignite the intellectual curiosity of the student. Once that was achieved, the student's appetite for knowledge and understanding powered the entire educational process, in and outside the classroom, during and after formal education. This Edtech testbed is an experiment in creating digital learning resources designed to re-ignite curiosity-driven learning by starting, not from the curriculum, but from the things that fascinate young people most.

Enhancing curiosity-driven learning

The 'stick' of examination performance is not the only way to drive up educational standards. This testbed will focus instead on the 'carrot' of curiosity-driven learning. This means targeting the 'thriving needs' of students: in this case, the material is studied for its intrinsic interest, rather than as a means to an end (as in the case of curriculum-driven learning). The primary target in this case is the student: the objective is to directly engage their interest by situating curricular material *outside* the formal academic setting and approaching it from the direction of those things which have already engaged the student's interest. Put differently, the objective of this curiosity-driven experiment is not to make learning *easier*: it is to make it more enjoyable, fruitful, productive, stimulating, and ultimately to make the educational process self-sustaining by firing the young person's curiosity about the world and all the different modes of understanding it.

Putting the student experience first: a B2C proposition

Given the fact that this testbed targets students pursuing their own interests in their free time, every aspect of the user experience must be scrutinized and tested. At every point in the user experience, curiosity must be provoked which will lead students them further into the network of resources and experiences. Such points of interaction include the following:

- Potentially interested user: Looking at the various points of entry, including those from curricular material, speaking to a teacher, or via social media.
- First exploration of the material: accessing the materials online, first steps for delving into the material.
- Options for exploration: curated and un-curated pathways, lucky dips, networks of options radiating out from a single point of entry, variety of navigational aids.
- Regular visitors: question-and-answer function; chat sessions; feedback options; requests; reviews; links out to curricular material.
- UX/UR expertise is clearly necessary to optimise these points of interaction.

Goals

The central goal of this Edtech testbed is to use Oxford collections, expertise, and technology to create innovative means of firing the curiosity of young people raised on fantasy literature and cinema to take an interest in subjects they might otherwise neglect or dislike, beginning with science and mathematics. Piloting means of achieving these goals will require work at four different levels: content creation, platform development, business model, and operating model.

Content creation

- *Objects* from Oxford and elsewhere will be identified as the basis of props and sets of the Harry Potter series, beginning with those of a mathematical or scientific nature.

- *Expertise* in explaining those objects will come from the History of Science Museum, Mathematics Faculty, and the Centre for the History of Science, Technology and Medicine.
- *Technology* necessary to make those objects and explanations as engaging and interactive as possible will be sought from in and outside Oxford (e.g. from the Oxford XR Hub and Pomona Pictures, respectively).
- *Worked examples* (small in number, high in quality) will be fully developed to provide the basis of testing with school pupils of various ages.
- *Further content development* will consider how similar methods can be used to arouse the curiosity of young people in other areas of the academic curriculum.

Platform development

Platform development will reconsider how Cabinet could be overhauled to facilitate the more innovative aspects of this technology, ensuring that further development of the Cabinet platform is informed by the results of this experiment.

- Gather examples of technology relevant to the challenge of curiosity-driven learning.
- Consider whether different modes of visual presentation and interaction need to be provided for curiosity-driven materials and at different educational levels.
- Consider how best to link curiosity-driven material aimed at school pupils to curricular material at various educational levels.
- Consider best means of training new contributors in devising curiosity-driven materials.
- Consider broader implications of digitally-delivered materials for curiosity-driven learning for the transformation of educational processes, methods, and institutions at all levels.
- Future planning will consider how such a platform could be further enhanced through the use of AI, ML, XR, data lakes, etc., and begin to generate proposals for further funding necessary to scale the content creation and platform development.

Business model

Business models will then be explored for curiosity-driven pedagogy. These materials are not directly tied to curricula, so a B2B partnership with a major publisher of textbooks (as proposed for The Medicine Cabinet) is inappropriate. Since these materials can only level up education if they are open access, a B2C model is suitable. By this we mean educational resources made available through a business model in an open way that involves interactions between a digital content providers and consumers/public users.

One plan is to pursue philanthropic funding to support this. Given the origins of the project in the Harry Potter novels, J. K. Rowling may be one possible source. Given the even closer relationship with the Harry Potter films, Warner Bros. Studios is another options. Educational and social charities and the film industry may provide alternative sources of funding. AWS Studios has also been suggested as a possible backer. The success of other Edtech projects in using the philanthropic funding model will also be studied (e.g. https://www.weschool.com/). This aspect of the testbed will therefore explore philanthropic options for funding the growth and implementation of this approach.

Contrariwise, the material generated by this testbed will be developed as proof of concept for accessing such funding.

At the same time, we will also explore other fundings models with members of the Said Business School and the Centre for Teaching and Learning which generate revenue for growth and sustainability without chagrining the end user for access to this educational material.

Operational model

Experiment with external experts and state-of-the art facilities. Our enormous and diverse organisation works in silos, with most component organisations inward-facing. As well as interacting more fruitfully with cognate initiatives inside the University, we also need to realign ourselves with the world around us and become much more mindful of what is happening outside. With this challenge in mind, this test bed will attempt to break down both the internal barriers between communities within the University and the barriers with the outside world. The latter will involve experimenting with outside experts, shared facilities, and toolsets. We will also identify 'someone who has done it' to help explain what really works and inform us about the state-of-the-art. Before we create sources of this expertise in house, we need to work with external partners to demonstrate what is possible.

The disruptive goal setting in this test bed is actually a domain–specific educational technology service conceptualisation. It revolutionises 'verified, deep-domain knowledge-fuelled, academic-consumer education services relations'. The content arises from deep domain knowledge. This means it is authoritative in a way that Wikipedia is not. The contribution of content is fuelled by the desire of academics to communicate the interest and importance of what they do, of universities to 'give back' to the general public, and to play a positive role in a media environment which has been corrupted by fake news, conspiracy theories, misinformation, and junk. If we set a high standard, the prestige of the platform will also incentivise contributions (e.g. when rebranded 'MasterClass' or 'MasterPieces' or something along those lines).

Research scope

Mathematical instruments

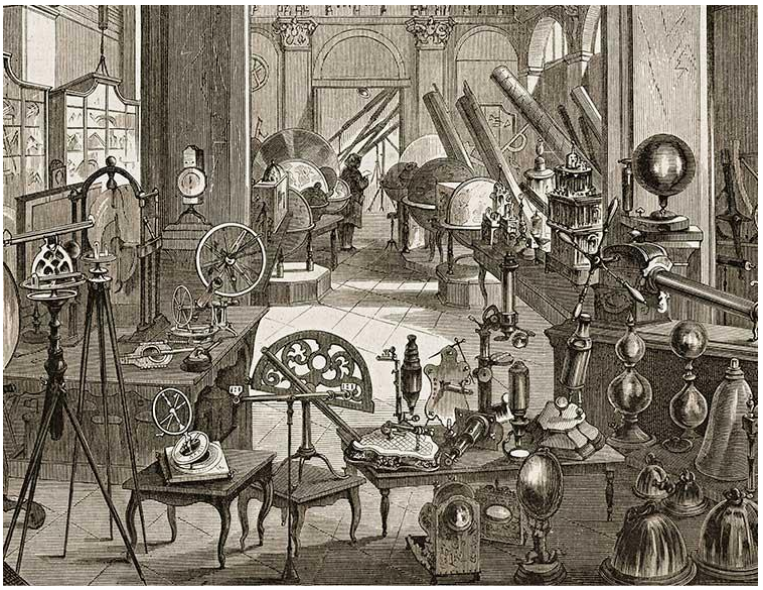
Half an hour into one of the post-Harry Potter films, 'The Crimes of Grindlewald', we visit the young Dumbledore's lecture room (This still is from a YouTube extract at 1:39).

Behind him are two objects.

One is a **piece of turned ivory** straight out of an early 17th-century German collection (cf. this from the Gruenes Gewolbe in Dresden). HH has a new DPhil student working on this collection, who can provide expert research assistance.

The other is the **mathematical pillar** from the Museum of the History of Science -- a unique and rather mysterious object, given to the University c. 1620. Its purpose seems to be to relate the Tower of the Five Orders to the five Platonic Solids clustered around its base. It was originally displayed in the Bodleian but is now in the History of Science Museum. It has already been captured in 3D and briefly described on Cabinet.

Other views of Dumbledore's Office (such as those from the Harry Potter World in London, included below) contain many more mathematical instruments and models characteristics of late medieval and Renaissance cabinets of curiosities.



For instance, the display cabinet above is from the set of Dumbledore's Office. It roughly approximates a cabinet of mathematical instruments of the sort which proliferated in the eighteenth century (below). But the architecture of the cabinet is gothic, and the instruments within it are mostly characteristic of the 16th and 17th centuries: some are based on astrolabes, others on armillary spheres, others on (not so) early microscopes, telescopes, and orreries. Amongst the most interesting objects are the **polyhedra**, which provide a wonderful opportunity to stimulate young people's interest in geometry (this idea is further developed below).

In the same set, the three objects on pedestals are based on the armillary spheres which were standard equipment for a professor of astronomy throughout the latter Middle Ages and Renaissance. Cabinet already contains commentary on a famous example in the HSM complete with videos explaining how these instruments worked.

The huge clock mechanism which features prominently in the later films clearly derives from the astronomical tower clocks of the late medieval period, and specifically from the most famous of these: that in the Old Town Square in Prague. There is a great deal to be said

about what these dials mean and why these clocks proliferated at this time (some of it already on video).

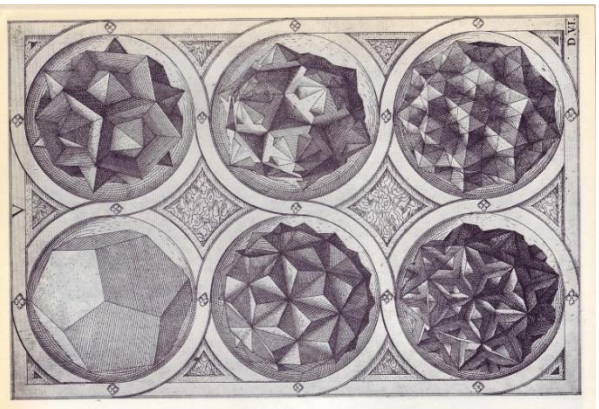
Prime focus: polyhedra

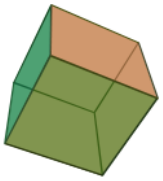
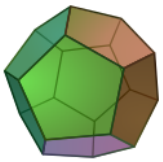
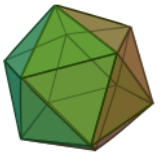
Judging from the images reproduced above, Dumbledore's favourite object was the stellated polyhedron: at least five of these can be seen on a single shelf in his cabinet below.

The five Platonic solids

Uniform polyhedra are solids all the faces of which are composed of regular polygons and all vertices are identical in shape and size. Regular polygons – triangles, squares, pentagons, hexagons, octagons, and so on – are basic figures which every child encounters in work on elementary geometry. Elementary understanding these objects is therefore within the reach of students of even very elementary mathematics.

The most basic uniform polyhedral are the Platonic solids: the only five polyhedra composed of identically sized regular polygons with identical vertices.



Tetrahedron	Cube	Octahedron	Dodecahedron	Icosahedron
Four faces	Six faces	Eight faces	Twelve faces	Twenty faces
				
(Animation, 3D model)	(Animation, 3D model)	(Animation, 3D model)	(Animation, 3D model)	(Animation, 3D model)

The purpose of this foundational part of the testbed, however, is precisely *not* to introduce these objects by reference to their abstract geometrical properties. Instead, the strategy is first to show students their fascinating and beautiful properties. It is no coincidence that these objects, and others derived from them, are found in the office of the greatest wizard in Hogwarts: their 'magical' properties are so remarkable that they have been the basis of 'sacred geometry' since ancient times.

They are called 'Platonic' because **Plato** hypothesized in the *Timaeus* that they correspond to the five elements of classical physics: the four terrestrial elements of earth, water, air, and fire, and the fifth celestial element known as the 'aether' or 'quintessence'.

The **sixteenth century** fell in love with this stuff after the refinement of perspective allowed artists to draw these fascinating figures for the first time. The revelatory work was Wenzel Jamnitzer's *Perspectiva corporum regularium* of 1568. Another set of images from that book (related to the five elements) can be found here.

The great astronomer Johannes **Kepler** went so far as to propose that the entire solar system was structured by a set of nested Platonic solids (in his *Mysterium cosmographicum* of

1597). The Platonic solids can also be found clustered around the 'mathematical model' (in the first image above) which is also crowned with a dodecahedron. If we want to awaken children's interest in geometry, for instance, there is no better way than merely *showing* them some of the 'magical' properties of these amazing objects.

Animating their 'magical' properties

Some of these properties are already captured in a rather crude way in openly accessible YouTube videos.

- https://www.youtube.com/watch?v=voUVDAgFtho
- https://www.youtube.com/watch?v=BsaOP5NMcCM (esp. from 4:00 onward)
- https://www.youtube.com/watch?v=bUw44jvP0T4
- https://www.youtube.com/watch?v=X8Q6MowNfW4
- https://www.youtube.com/watch?v=osg4LgggbqI
- https://www.geometrycode.com/metatron-cube-3d-animation-flower-of-life-platonic-solids-video/
- https://www.youtube.com/watch?v=5CSGs4zEzSg
- http://dmccooey.com/polyhedra/Platonic.html (an interactive app)

Similar videos can be found relating the very special category of Platonic solids to the larger group of Archimedean solids and derivative stellated polyhedral such as those in Dumbledore's cabinet: he appears to have been particularly fond of great stellated dodecahedra.

Polyhedra

The basic challenge here, in other words, is to imagine what kind of educational materials could be created by a collaboration between

- a gifted expositor of mathematics to the general public, such as Oxford's **Marcus du Sautoy** (who introduces the Platonic solids in this extract from a longer programme which is part of a BBC series called The Code);
- educational specialists adapting the material to the appropriate educational level;
- graphic designers, animators, and cinematographers such as those at Pomona Pictures;
- composers capable of further enriching the experience with just the right musical soundtracks;
- and perhaps historians of science and mathematics capable of linking these images to the late Medieval and Renaissance world which populates Dumbledore's Office.

Broader setting

There is exciting potential here to make the whole user experience as magical as the objects themselves.

- A basic solution would be to click on objects in an image of Dumbledore's Office to link through to animated or interactive materials explaining what they are and how they work.
- A more exciting (second-generation?) option would be to handle this whole testbed in virtual reality space, where the room and the objects are all available in 3D.

This is potentially the most technically ambitious and experientially exciting of the three EdTEch testbeds proposed here.

Activities, Owners, Schedule

Provisional task list

1. **Bridge:**
    a. Bridge the gaps between the University, the people it's meant to serve, and the changes happening around it (how to change and how quickly).
    b. Collect evidence of how digital technology and new ways of working are being used by peers and competitors in the education technology market to win market share, increase revenue, and decrease costs (AWS, OUP, UK, US and Italian Universities).
    c. Collect and record customer insights into the new offerings and experiences that are already winning a greater share of their time, spend, and loyalty (School Trusts in Oxfordshire, AWS UK Education Sector sales reps, Oxfordshire County Council and iHUB).
    d. Select and write up in internal recommendation paper about the technologies that could improve and add value to our existing (e. g. AWS Educate, Academy, AWS education blog, and AWS Partner network of edtech service providers).
    e. Verbalise the vision that succinctly describes the kind of transformation needed to address these opportunities and threats, and that helps us win support from needed stakeholders, partners, and investors.
    f. Present to the leadership group willing to sponsor and guide transformation by providing oversight, evaluating progress, and mitigating barriers throughout the programme (PVC Digital, GLAM IT, Humanities Division, History Faculty, DiSc Board, DiSc Lab/Hub's Spokes in other divisions).
2. **Scoping:**
    a. Invite a group people (including historians of late medieval and Renaissance art and science) to watch through the Harry Potter series looking for relevant material, useful assets and topics for co-creation
    b. Contact Stuart Craig, and others at Warner Brothers for information on the sources of various props and sets.
    c. Prioritize and identify lists of objects for inclusion, prioritizing found assets for leveraging, to get started sooner or with less funding.
    d. Identify experts able to write commentaries on the top-priority objects. This way, we create cross-functional teams to begin iteratively working to achieve the project outcomes Identified missing skills and resources, and begun the process of filling them.
    e. Define technical aspirations for this limited testbed (with first sketch of more ambitious options which might follow in a second phase of work).
3. **Recruiting and commissioning**
    a. Commission imaging and image processing for prioritized list of objects
    b. Recruit and brief selected specialists on those objects
    c. Recruit school teachers for focus-group feedback on material produced
4. **Delivery in iteration**

a. Build in short cycles, test with real users, and improve as you go to know which innovations can scale. Producing actual results in cycles of 'ideate, build, test, learn, improve'.
b. Provide guidance to specialists and assistants in developing commentary on each point of contact at multiple different educational levels
c. Merge image and commentary on Cabinet
d. Present draft material to schoolteachers for feedback
e. Revise draft material in response to feedback

5. Planning

a. Reconceive basic platform for more immersive experience in second phase of work
b. Revised guidelines for best practice in line with feedback
c. Document other lessons learned for future reference

Justification of resources

Co-PI: Dr Silke Ackermann, Director, History of Science Museum (GLAM). **Role**: curating exposition of material on late medieval and Renaissance mathematical and scientific instruments; liaison Vision 2024 (plans for the centenary of the HSM). **Participation confirmed**

Co-PI: Prof Marcus du Sautoy OBE FRS, Simonyi Professor for the Public Understanding of Science, Faculty of Mathematics (MPLS). **Role**: leading the presentation of polyhedra. **Participation confirmed**

Co-PI: Prof Howard Hotson, Professor of Early Modern Intellectual History (History Faculty) and Academic Director, Digital Scholarship @ Oxford (Humanities Division). **Role**: First-stage proposal formulation; coordination of academic content; liaison with DiSc and HMC Edtech testbed series. **Participation confirmed**

Creative and Industrial Advisor: Charles A. Matz (AIA RIBA CID), Principal and Executive Director of a multi-business unit holding company engaged in multiple sectors and within varied industries (Tech and media accelerators, engineering and the built environment, multi-media systems, motion-capture industry tech, museum and galleries, higher education). **Role**: Situating the project at the interface between digital humanities and multiple potential markets. **Participation confirmed**

Staff cost for senior researchers, research assistants, casual contracts. Costed for the period from 15 February – 31 May 2022. £8000

Technical support from GLAM IT (for AWS cloud and ML tool demonstration), Oxford XR Hub (for 3D visualisations), contractors (e.g. Cloud Mantra or Cirrus HQ who worked with GLAM IT already). £5000

Professional services provider for XR, AI/ML, user experience (e.g. Pomona Pictures– Positive Customer Journeys, studio facility renting to test content creation). £7000

AWS cloud provision and solution architect support (e.g. James Grant) £5000

Total: £25,000.

Outcomes and Impact

Concrete outcomes

Concrete outcomes of this testbed project will include

1. A core set of high-quality *educational materials* using objects from Dumbledore's Office to provoke curiosity and spontaneous interest in aspects of science and mathematics amongst school pupils who might not appreciate them when placed in a formal curricular setting.
2. The report of a *testing process*, assessing the response of school pupils at various levels to the pilot educational materials described above, including specific proposals for refining content, presentation, and user experience at a further project stage.
3. Specific *proposals for scaling up* this approach by prioritizing areas for further content creation and technical development.
4. The outline of a *business plan* for curiosity-driven educational materials, including the pursuit of philanthropic funding.

Procedural outcomes

Procedural outcomes, deriving from our focus on the external and internal bridging and iterative co-creation, will include the establishment of:

1. Cross-functional project teams that work collaboratively to iteratively create solutions that achieve goals aligned to the objectives.
2. Solutions that start as simple prototypes and get bigger and more complex incrementally as they're tested and improved with real users.
3. Results and evaluation processes that reveal the most valuable solutions which should therefore be scaled.
4. Benchmarks from testing that will inform each solutions' key performance indicators to make the case for why it should be scaled and what value it brings.
5. New ways of working that have been trialed by the iterative teams, proving which are successful in the context of our organization.
6. The 'new business as usual': disseminated new innovations and ways of working showing us thriving in changing environments.

Impact

Impact of this test bed can also be assessed in form of 'leverage' (Herbert (2017, p. 20)[1]

[1] Herbert, L 2017, Digital Transformation : Build Your Organization's Future for the Innovation Age, Bloomsbury Publishing Plc, London. Available from: ProQuest Ebook Central. [29 January 2022].

- Shared successes internally to win influence from previously resistant parties, and access greater resources and freedoms to expand.
- Promoted successes externally to attract new partners, new hires, and new users in preparation to scale.
- Identified the best areas to scale based on the amount of influence, resources, assets, and support gained.
- Won buy-in from staff and management to increase the instances of organic adoption as the programme grows into new areas of the business.
- Anticipated and mitigated threats, such as retaliation from the competition, that often accompany an organization announcing transformation successes.

Real digital transformation isn't about getting an organisation to use a specific set of new technology; it's about the organisation's ability to react and successfully utilize new technologies and procedures – now and in the future. For most, this includes adopting processes that allow the leadership and staff to investigate, experiment, and strategically employ new technology on an ongoing basis.