IMPERIAL

Old Centralians' Trust
CITY AND GUILDS COLLEGE ASSOCIATION

rEaCt
EPSRC Centre for Doctoral Training in Next Generation Synthesis & Reaction Technology

ICONIC
Innovative Continuous Manufacturing of Industrial Chemicals

POPCORN FACTORY: SCIENCE AT SCALE

POST-PROJECT REVIEW

Abstract

This report outlines the development and delivery of Popcorn Factory: Science at Scale, a public outreach exhibit demonstrating key chemical engineering principles through a continuous popcorn manufacturing system. The project successfully met all objectives, engaged thousands of visitors across multiple events, and will continue to serve as a reusable platform for future outreach.

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Executive Summary

The Popcorn Factory: Science at Scale exhibit was a tremendous success, attracting thousands of visitors and introducing diverse audiences to the field of chemical engineering through an engaging, hands-on demonstration of continuous manufacturing and fluidised bed technology. Presented at multiple high-profile events throughout the year, the exhibit consistently drew large crowds and received outstanding feedback. All objectives outlined in the original proposal were fully achieved. The exhibit was an interactive experience, showcasing real-world engineering applications, and highlighting the innovative work of our lab. The project was completed under budget, with a remaining balance of £265.68, which will be reallocated to upgrade and future-proof the exhibit for continued use in upcoming outreach activities.

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1 Organisational Summary

1.1 Partnerships and Acknowledgements

The resounding success of the project would not have been possible without the financial contribution of our partners, and the support from the departments of chemical engineering and chemistry at Imperial College London.

1.1.1 Partnerships

The project received financial support from the Centre for Science Communication at Imperial College, REACT CDT (Imperial), IConIC partnership (Imperial), the Department of Chemical Engineering (Imperial) and The Old Centralians' Trust, an independent charity. Both REACT CDT and IConIC partnership are partially funded by the EPSRC – a public body – and as such have a requirement to carry out outreach activities.

1.1.2 Acknowledgements

The project team ("we") would like to acknowledge the support provided by the services at the Department of Chemical Engineering at Imperial. Special thanks to the Mechanical Workshop team who manufactured the stainless-steel parts, and the Electrical Workshop for providing technical expertise on the electrical system and ensuring its safety.

We are grateful to the members of the Reaction Engineering and Catalytic Technology (REaCT) group for helping with the preparation and delivery of the exhibit.

We would like to extend thanks to Professor Klaus Hellgardt, Imperial, for allowing us to use the resources of his lab to carry out tests and construction.

Furthermore, we would like to thank Doctor Anna Hankin, Imperial, for the use of the department's outreach resources and additional funds.

Finally, we would like to extend special thanks to Bhavna Patel and Georgia May, from IConIC and REACT CDT respectively, for providing invaluable support in navigating many administrative challenges of the project and helping to secure the necessary funding.

2 Staffing and Responsibilities

The project was entirely developed and lead by students at Imperial.

The operating procedures and all technical documentation are available upon request from REACT. Risk assessments and operating procedures are attached to the device as hard copies.

The administrative support was provided by Bhavna Patel (IConIC) and Georgina May (REACT CDT)

Name	Responsibilities	Affiliation
Siwek, John	Team lead	REACT CDT, React Group
McQuade, Aaron	Design, construction, events	REACT CDT, React Group
Perez Tabarnero, Ines	Design, construction, events	REACT CDT, Chris Tighe
Shields, Matthew	Design, construction, events	IConIC, React Group
Patel, Bhavna	Admin authorisation, Event (Weird Science)	IConIC, Staff
Gulsoy Serif, Zeynep	Events	IConIC
Rahman, Redwan	Events	React Group
Alhashmi, Essa A S M	Events	React Group
Agrawal, Diya	Events	Chen Group
Xiao, Muye	Events	REACT CDT, React Group

3 Project and Events Overview

3.1.1 Overview of the Technical Details

The popcorn exhibit was built around a fully functional, visually engaging continuous fluidized bed system designed to showcase key chemical engineering principles such as fluidisation, heat transfer, and process control.

At the core of the system is the process chamber, constructed from a 5 cm outer diameter borosilicate glass tube. Inside this tube sits a perforated stainless steel distribution plate, which is elevated within the chamber to make the fluidisation process clearly visible to the audience. This plate plays a critical role in distributing hot air evenly through the bed of corn kernels, enabling consistent and effective popping.

To improve safety and thermal insulation, the process chamber is enclosed within a larger 10 cm outer diameter borosilicate glass tube. This outer layer provides a buffer between the hot inner chamber and the environment, keeping external surfaces cooler while preserving visibility.

The chamber is structurally supported by a custom-built aluminium manifold and a stainless-steel base, which not only hold the components securely in place but also help optimise the airflow profile into the chamber.

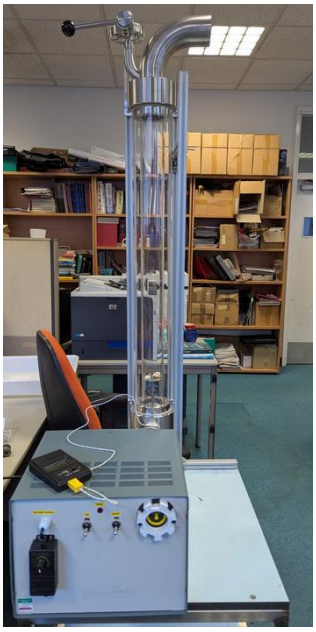
Mounted at the top of the glass columns is a metal top assembly, which houses the corn hopper and an outlet pipe. Fresh corn is introduced into the chamber via a manual lever-action dosing system, allowing controlled loading of kernels during operation. Once the corn reaches popping temperature, the lightweight popped kernels are ejected from the process chamber by the upward airflow and collected in a tray positioned above the machine.

The air supply system uses an electric fan to draw in the surrounding air. This air is then passed through electrical heating elements where it is rapidly heated to the desired setpoint. The hot air enters the process chamber from below the distribution plate, enabling fluidisation and popcorn production.

All power, controls, and heating functions are housed in a dedicated metal control box. It contains the power distribution system, temperature control, and the fan. This integrated control unit allows operators to safely adjust temperature and air flowrate.

At peak time, the machine produced approximately 15 kg of popcorn per hour, averaging 5 portions per minute. The system maintained a continuous flow of fresh, oil-free popcorn, providing both an educational and sensory experience for attendees.

The machine was completed and first tested on the 6th of February 2025 (Mk.1) and underwent several minor upgrades, and one major revision for the Great Exhibition Road Festival from the lessons learned during the previous events (Mk.2) and to improve production rate.



Mk.1 – Weird Science

Mk.2 – The Gear Exhibition Road Festival

3.1.2 Overview of the Presentation Delivery

The success of the popcorn exhibit relied not only on its engineering design but also on its immersive, multisensory experience. The sound of kernels popping and the distinct smell of freshly made popcorn were intentionally used to draw in large numbers of visitors throughout the event. These sensory cues proved highly effective, often leading to large audiences.

Once a group gathered, the team would begin the oral presentation by warmly welcoming visitors and introducing the machine. The demonstration was structured around the path of the air through the device: from intake to heating to fluidisation and finally to popcorn ejection. In smaller groups, this explanation became more interactive: visitors were invited to touch the intake fan, trace the air duct visually, and think critically about what was happening at each stage of the process.

Next, fresh kernels were loaded manually from the hopper using a lever mechanism. This moment served as a natural segue to introduce key scientific principles, particularly fluidisation and heat transfer, explained in the context of popcorn production.

As the first kernels began to pop, the presenters engaged the audience by asking, *"Does anyone know why popcorn pops?"* This sparked discussion around pressure buildup and phase change, often drawing a parallel to a boiling kettle to illustrate the rapid escape of steam from within each kernel.

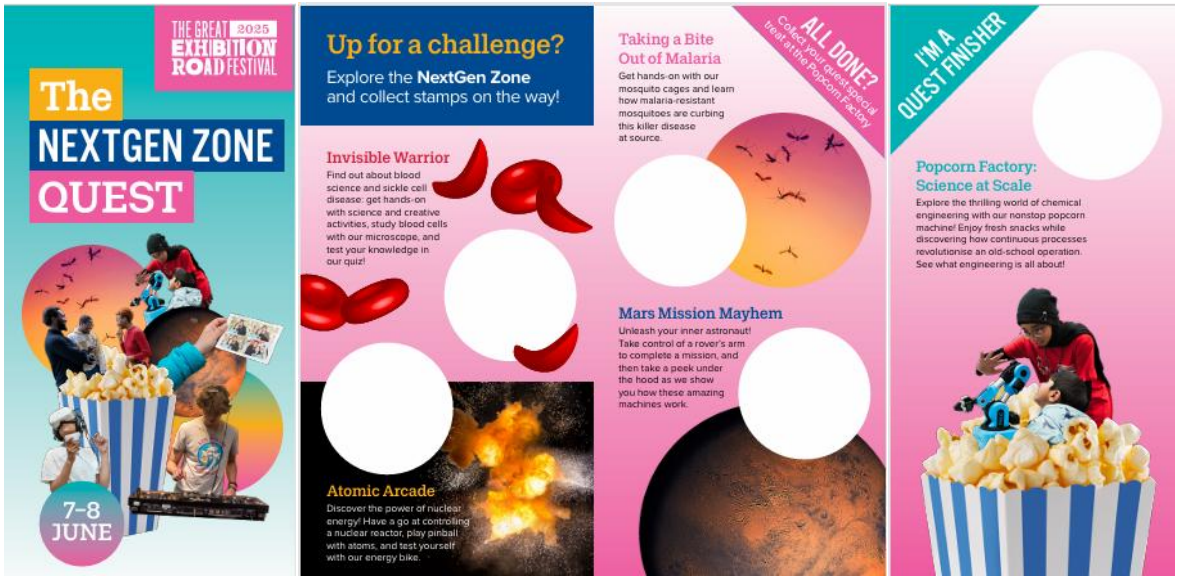
When the popcorn began flying out of the chamber, the focus shifted to separation and continuous processing. Audiences were asked to consider *why popped corn exits while un-popped kernels remain inside*. This prompted discussion of aerodynamic drag, density differences, and how this natural separation forms the basis for a continuous, high-throughput process, in contrast to the batch-style popcorn making they might be familiar with at home.

As the collection tray filled, the team introduced the concept of continuous manufacturing and used it as a gateway to explain what chemical engineers do in practice. Real-world examples were shared, including fluidised bed reactors in industry and how similar principles are used to manufacture everyday products such as fertilisers, medicines, plastics, and energy. This broader context helped visitors appreciate how chemical engineering plays a vital role in enabling modern life.

Finally, the team handed out popcorn bags to the audience, which served both as a fun takeaway and a memorable reinforcement of the learning experience. Team members remained on hand to answer questions, discuss the exhibit in more depth, and engage in one-on-one conversations with particularly interested visitors.

This thoughtful, layered approach to public engagement, moving from sensory attraction to interactive explanation, then to conceptual understanding and real-world relevance, was key to the exhibit's success. It allowed visitors of all ages and backgrounds to connect with chemical engineering in a meaningful and enjoyable way.

Due to the exhibit's popularity a system was put in place at the Great Exhibition Road Festival to encourage visitors to explore other exhibits in the area. Attendees were asked to collect stamps from several other key exhibits before redeeming their portion of popcorn. This helped distribute foot traffic and ensured that the popcorn station acted as both a highlight and a reward at the end of a broader learning journey.



3.1.3 Overview of Decommission Plan

The machine and its associated materials are currently kept in offices in the department of chemical engineering at Imperial – explicitly kept out of contaminated areas. As of December 2025, it is undergoing a final upgrade to increase automation.

Following the work, it will be looked after by the React Group (Klaus Hellagrdt) and the department and used in future events. The remaining funds will be used to improve the machine and obtain spare parts.

3.2 Summary of Events

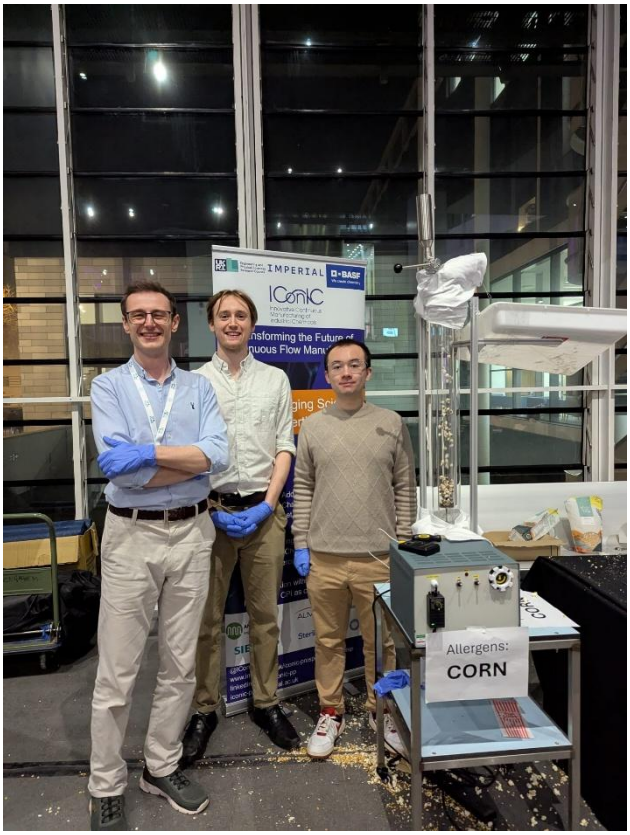
The Popcorn Factory: Science at Scale exhibit was presented at four major outreach events throughout the year, summarised in Table 1, each offering a unique opportunity to engage diverse audiences with chemical engineering through an exciting, hands-on experience. The first public appearance of the exhibit was at Imperial Lates: Weird Science, a popular after-hours event series hosted in South Kensington and curated for adult audiences. The event celebrates the unusual and unexpected side of science, making it a perfect venue to debut the popcorn machine – which was completed and tested for the first time exactly 15 minutes prior. The exhibit drew unexpectedly large crowds, prompting the team to adapt quickly by switching to a lecture-style presentation. Despite a minor clogging issue due to popcorn overfeeding, the machine performed well and provided valuable insights into improving both the hardware and visitor engagement strategy. Next, the exhibit took part in International Women's Day in Engineering, hosted by the Department of Chemical Engineering. Aimed at inspiring secondary school students, particularly young girls. The event offered a calm but meaningful platform to introduce future engineers to the excitement of scientific problem-solving. The exhibit ran smoothly with support from departmental staff. At the White City Discovery Day, a family-focused event designed for local communities, the machine delighted younger visitors, many of whom had the chance to operate it themselves. Around 120 participants interacted with the exhibit, making it a highlight of the day. Finally, at Imperial's flagship outreach event, the Great Exhibition Road Festival, the upgraded popcorn machine took centre stage in the Science Museum's Next Gen Zone in The Smith Centre. Over two days, it attracted more than 3,000 visitors, producing over 1,400 portions of popcorn and serving as the final reward in a science-themed stamp trail. This marked the exhibit's most successful outing, demonstrating its full capability as a high-throughput, crowd-engaging, educational platform.

Table 1 – Summary of Events

Event	Date	Location	Exhibit Revision
Imperial Lates *Weird Science*	6th of February	Imperial College, South Kensington	1.0
International Women's Day	8th of March	Imperial College, South Kensington	1.1
Discovery Day	22nd of March	Imperial College, White City	1.1
The Great Exhibition Road Festival	7th & 8th of June	Science Museum, South Kensington	2.0

3.2.1 Imperial Lates, *Weird Science*

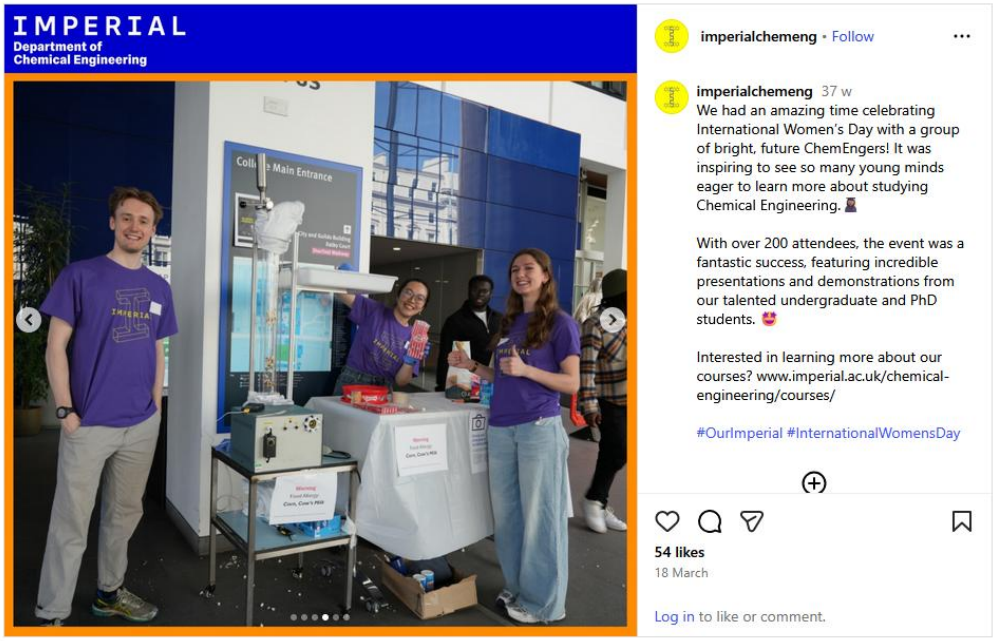
Imperial's science outreach team is the organiser behind Imperial Lates – a series of events aimed at an adult audience, hosted in South Kensington. The exhibition titled "Weird Science" showcased some of the interesting and quirky work offered by Imperial and was a part of the original proposal. This was the first event the machine was shown at and used to test the device and develop the presentation aspect.



The exhibit was exceptionally popular with the public, drawing a massive crowd. To accommodate the unexpected number of simultaneous visitors, the team switched to a lecture style delivery explaining how the device worked and its connection to the IConIC continuous manufacturing ethos. The visitors were then given popcorn before moving on to see other exhibits, with some visitors loitering around to watch the popcorn fly inside the machine. The team experienced one technical issue with clogging of the tube due to popcorn overfeeding which was resolved by carefully taking off the top assembly.

3.2.2 International Women's Day

The department of Chemical Engineering at Imperial contributed towards the International Women's Day exhibition in South Kensington. The event was aimed to promote engineering to secondary school students, with a particular focus on young girls. The team was joined by support staff from the department's admin team. The event went by without any issues.



3.2.3 Discovery Day

Discovery Day family activities are a series of free public events for families within the White City catchment area, organised by Imperial's public engagement team. This event provides a unique opportunity to share the wonder of science with the local community, provide activities for families in the area and to promote a sense of community and family learning. This Discovery Day will showcase awesome science and research, providing accessible content for families new to the space. At the Discovery Day the team saw 120 visitors interact with the exhibit, especially school children who had a chance to operate the machine.

3.2.4 The Great Exhibition Road Festival

The festival is the largest outreach event organised by Imperial on an annual basis. It takes places across the South Kensington campus, the Exhibition Road and the local Museums. The popcorn machine was part of the Next Gen Zone located at the Smith's Centre in the Science Museum. The zone generated massive queues and run at maximum capacity for two days straight, attracting over 3000 visitors.

For the festival the machine was upgraded the popcorn machine to improve operating performance and popcorn throughput. The heat insulation was also replaced, which dramatically improved the look of the exhibit, as well as its resilience.

4 Review of Aims and Objectives

This section reviews the aims and objectives stated on the project proposal and provides an outlook on whether they were achieved.

4.1 Review of Aims

The project achieved the general aims outlined in the proposal as follows:

4.1.1 Develop and present an interactive fluidized bed popcorn machine

The project successfully delivered a fully functional and visually engaging continuous fluidized bed popcorn machine. The design featured a transparent process chamber, allowing visitors to observe popcorn kernels suspended and popped by a rising stream of hot air. This provided a direct and compelling demonstration of fluidisation. The machine operated continuously, with a hopper feeding in fresh kernels and popped corn being ejected automatically, showcasing the transformation of a familiar batch process into a high-throughput, continuous system. Visitors were not only able to observe this transformation, but also experienced it up close through sound, smell, and movement, making it a truly immersive experience.

4.1.2 Provide a hands-on, safe environment for the public to experiment with parameters

The machine was engineered with adjustable temperature and airflow controls, allowing visitors—especially younger audiences—to explore how process variables affect popping behaviour, fluidisation, and product separation. The physical principles of heat transfer, drag, and density differences were explained as visitors observed real-time changes in the system. At smaller events like Discovery Day, schoolchildren were even invited to operate the lever for loading kernels and control airflow, offering a truly tactile learning experience within a safely controlled setup.

4.1.3 Support the exhibit with visual aids and clear explanations

To enhance accessibility, the team created a custom poster explaining the science of popcorn popping and fluidisation. During live demonstrations, simple analogies such as comparing escaping steam in a popcorn kernel to a boiling kettle, or using a mini parachute to explain drag forces, helped bridge the gap between complex engineering concepts and audience understanding. These aids, paired with dynamic presentations tailored to audience size, ensured a consistently engaging and educational experience.

4.1.4 Offer technical insights into the processes involved

The exhibit served as a launchpad for discussing industrial applications of chemical engineering, including fluidised bed reactors used in polymer production, catalytic processes, and power generation. The simplicity of the popcorn machine's control system—managing heat and air inputs—was effectively used to introduce broader concepts in process control and system dynamics, allowing visitors to appreciate how engineers scale up and optimise processes in the real world.

4.1.5 Incorporate safety measures and staff support

A full risk assessment was conducted prior to the exhibit's launch, and the machine was designed with multiple safety features, including insulated glass, secure housing for hot components, and electrical interlocks. During all public events, the exhibit was staffed by trained team members who not only delivered presentations but also ensured safe operation throughout.

4.2 Outlook on Objectives

The project achieved the objectives outlined in the proposal as follows:

4.2.1 Introduce the public to the field of chemical engineering

The exhibit used a familiar process—making popcorn—to introduce visitors to core chemical engineering principles such as heat transfer, fluid dynamics, and process control. By linking the demonstration to real-world applications in energy, pharmaceuticals, and manufacturing, the public gained a clearer understanding of the role chemical engineers play in modern life.

4.2.2 Demonstrate fluidized bed technology

A transparent, working fluidized bed system formed the centrepiece of the exhibit. Visitors could observe kernels suspended in hot air, simulating the behaviour of industrial fluidized beds. Adjustable controls allowed real-time changes to airflow and temperature, making the process interactive and easy to understand.

4.2.3 Educate and inspire curiosity

Live demonstrations encouraged audience participation, with presenters guiding visitors through questions and analogies to explain key phenomena. The exhibit sparked curiosity across all age groups and provided layered explanations suited to different levels of understanding.

4.2.4 Deliver a memorable and impactful outreach experience

With thousands of visitors across multiple high-profile events, the exhibit consistently drew large crowds and positive feedback. The sensory experience of sound, smell, and motion—paired with engaging presentations and fresh popcorn—made the exhibit a standout feature and left a lasting impression on the public.

4.2.5 Showcase the work of our lab

The exhibit highlighted the expertise and focus of our lab group, which is closely aligned with REACT CDT and the IConIC partnership, both of which supported the project financially. It reflected our core research themes of continuous manufacturing and process scale-up, demonstrating how our students apply chemical engineering principles to real-world industrial challenges. The project served as a public-facing example of the innovative, hands-on work conducted in the lab and its relevance to modern manufacturing.

5 Timeline

2024-11-16	• The Great Exhibtion Road Bid Acceptance • Invitation to Imperial Lates
2025-01-04	• CDT REACT Funding Awarded
2025-01-23	• ICONIC Funding Awarded • Dept. of Chem. Eng. Funding Awarded
2025-01-28	• OCT Funding Application Awarded
2025-02-06	• Prototype Mk.1 Tested • Imperial Lates Event
2025-03-08	• International Women's Day Event
2025-03-23	• Discovery Day Event
2025-06-02	• Device Mk.2 Tested
2025-06-07	• The Gear Exhibition Road Festival Event
2025-06-08	• Project Completion
2025-07-11	• Demonstration for Yr12 Visiting Work Experience Students

6 Accounts and Expenses

This section provides information on the sources of funding, the imperial account reference name where the money was kept, the remaining amount of funds as of 2025-06-08 which can be found in Table 1, and a list of expenses acquired which can be found in Table 2. The funds awarded from the Old Centralians' Trust were kept in a private bank account, referred to as “TOCT” in the accounting.

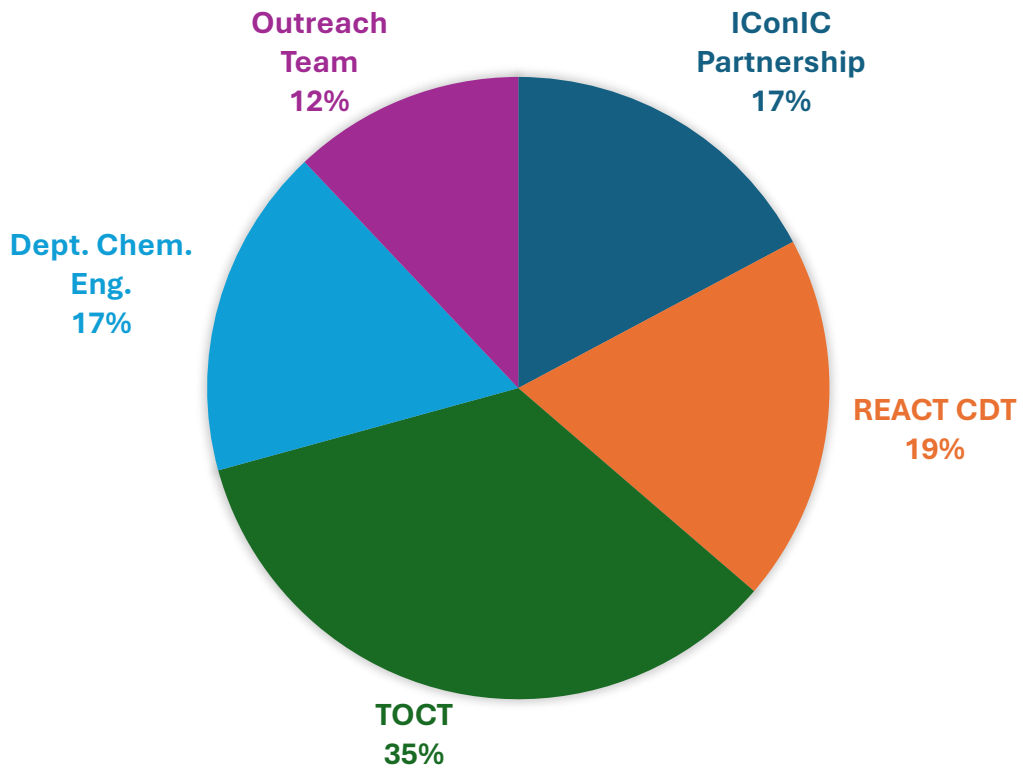


Figure 1 - Pie chart showing the funding source distribution

Table 2 – Outline of grant contributions and the remaining funds in the associated accounts

Name	*IConIC*	*Ines Project Account*	*Chem Eng Outreach Acc.*	*Old Centralians Trust*	
Source	*IConIC*	*REACT CDT, Imperial Outreach*	*Chem Eng*	*Grant*	
Account	*CHCM_PA1867*	*IC.CHTP.G98280*	*CENGS G10131*	*TOCT*	*Totals:*
Grant:	£500.00	£905.00	£500.00	£1,000.00	£2,905.00
Remaining:	£165.47	£81.22	£18.86	£0.13	£265.68

Table 3 - List of transactions

Item	***Executor***	***Account***	***Credit***	***Debit***
Tuffnell Glass VCC	JS	TOCT	£-	£90.95
Silicon Tubing	JS	TOCT	£-	£29.40
Hopper valve	JS	TOCT	£-	£78.80
High Temperature Super glue	JS	TOCT	£-	£7.99
Amazon small fittings 5mm	JS	TOCT	£-	£101.21
Heat gun x2	IPT	IC.CHTP.G98280	£-	£43.00
Aluminium Profiles	IPT	IC.CHTP.G98280	£-	£79.54
Aluminium profile fittings	IPT	IC.CHTP.G98280	£-	£18.00
Pipe top outlet	IPT	IC.CHTP.G98280	£-	£26.41
MECHANICAL WORKSHOP	JS	CENGS G10131	£-	£545.14
ELECTRICAL WORKSHOP	JS	CENGS G10131	£-	£190.00
Stainless Steel Pipe Fitting, Hex Coupling, 1/4 in. Female NPTPart #: SS-4-HCG	IPT	IC.CHTP.G98280	£-	£20.38
RS PRO aluminium box	IPT	IC.CHTP.G98280	£-	£81.11
carling toggle switch	IPT	IC.CHTP.G98280	£-	£11.33
PEEK Balls	IPT	IC.CHTP.G98280	£-	£57.00
9V battery	JS	CENGS G10131	£-	£6.00

Consum. Weird Science	Redwan	TOCT	£-	£25.00
Consum. Weird Science	Essa	TOCT	£-	£16.00
Tuffnell Glass VCC	JS	CHCM_PA1867	£-	£125.72
Hot gas blower RS comp	JS	CHCM_PA1867	£-	£158.54
Sanyo Denki DC Fan high flow	JS	CHCM_PA1867	£-	£56.58
Poster Printing	IPT	IC.CHTP.G98280	£-	£34.80
Insulation wool	IPT	IC.CHTP.G98280	£-	£179.15
insulation aluminum	JS	TOCT	£-	£42.84
max6675 k-type thermoc	JS	TOCT	£-	£4.99
Sensata Crydom PMP Series Solid State Relay	JS	CHCM_PA1867	£-	£123.96
MOSFET	JS	TOCT	£-	£7.39
MOSFET	JS	TOCT	£-	£4.99
oMRON e5c2	IPT	IC.CHTP.G98280	£-	£150.24
Motor & Power Shield for Arduino - WPSH03	JS	CHCM_PA1867	£-	£28.27
Sanyo Denki San Ace B97 Series Blower	IPT	IC.CHTP.G98280	£-	£37.31
Hot gas blower RS comp REFUND	JS	CHCM_PA1867	£158.54	£-
Consumables popcorn Discovery & Women	JS	TOCT	£-	£30.00
Consumables flavours Discovery & Women	JS	TOCT	£-	£39.98
Consumables gloves	IPT	IC.CHTP.G98280	£-	£4.40
Replacement breadboard	JS	TOCT	£-	£12.30
RS PRO aluminium box	IPT	IC.CHTP.G98280	£-	£81.11
Thermal insulation adhesive	JS	TOCT	£-	£42.84
Glue, LCD screen & Silicone k2	JS	TOCT	£-	£23.03
2 heat gun + 10kg popcorn	JS	TOCT	£-	£66.40
Consumables popcorn GERF	JS	TOCT	£-	£46.11
Team refreshments for 2 days GERF	JS	TOCT	£-	£31.92
Extra seasonings + water GERF	Aaron	TOCT	£-	£37.73
Outreach account settlement	JS	TOCT	£-	£260.00
Outreach account settlement	JS	CENGS G10131	£260.00	£-

7 Conclusion

The *Popcorn Factory: Science at Scale* project successfully met all its objectives, delivering a high-impact, interactive exhibit that introduced the public to key concepts in chemical engineering. By turning a familiar process into a continuous manufacturing system, the exhibit made complex ideas like fluidisation, heat transfer, and process control both accessible and engaging. It attracted large audiences across multiple major events and received consistently positive feedback, helping visitors understand the relevance of chemical engineering in everyday life. The exhibit also showcased the work of our lab and its partnerships with REACT CDT and IConIC, reinforcing our focus on scale-up and continuous processing.

The project was delivered safely, efficiently, and within budget. A remaining balance of £265.68 will be used to future-proof the device through small upgrades and maintenance, ensuring it remains ready for future outreach events. Overall, the project was a success technically, educationally, and in terms of public engagement. It provides a solid platform for ongoing science communication.

8 Supplementary Information

- A zip-file containing a selection of media elements (controlled access): link
- Video overview explaining the machine, taken just before the opening of the great exhibition road festival (Imperial controlled access): link
- Social Media posts:

Great Exhibition Road Festival (REACT CDT): link

Imperial International Women's Day March 2025 (Chemical Engineering, Imperial College): link

Imperial Lates Weird Science February 2025 (IConIC Partnership): link