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Collaborative GSK–University of Strathclyde doctoral research and training programmes: Transforming approaches to industry–academia engagement

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A global biopharma company, GSK, and the University of Strathclyde have developed an expansive and transformative research and training partnership originating in chemistry-aligned disciplines, with subsequent extensive expansion across further areas of the company. This has opened unique approaches for the delivery of collaborative research innovations while also enhancing the professional development and learning of GSK personnel, in addition to other embedded researchers and collaborating scientists, on a pathway towards more rapid and efficient discovery of new medicines.

Keywords: industry–academia collaboration; postgraduate research and training

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Introduction

Traditionally, collaborative working between industry and academia has taken the form of consultancy-based engagements, visiting lectures and seminars, or joint supervision of individual researchers working on specific projects. Over the last 2–3 decades, it has been realised that enhanced industry–academia engagement is crucial to the development of innovative solutions to business, industry, and societal research challenges,[(p1),(p2),(p3),(p4)] and dedicated investment for such partnerships has become increasingly accessible.[(p5),(p6),(p7)] As an example, the UK Research and Innovation (UKRI) Industrial Cooperative Awards in Science & Engineering (ICASE) provide direct funding for doctoral studentships where businesses and related organisations take the lead in arranging projects with academic partners.[(p8)] The typical studentship model for such engagements involves the student researcher being based primarily within the academic institution, with co-supervision and training opportunities provided by the industry partner, often (but not always) in the form of a secondment into the associated company. As related to this approach, national economic success, stability, prosperity, and competitiveness depend on appropriately advanced skills training for professionals to meet the associated requirements and demands from businesses. Not only do opportunities such as those exemplified by the UKRI ICASE framework promote knowledge exchange within business–academia partnerships, but the training experience for the postgraduate researcher within the context of a mutually beneficial collaboration is highly advantageous, leading to sought-after graduates entering the industry's emerging recruitment pool.

With specific regard to the development of new medicines, the pharmaceutical industry is vital to the UK economy, contributing over £13 billion per year.[(p9)] However, the industry faces increasing challenges in bringing new medicines to patients; innovation is constantly required, including that relating to the following areas: increased sustainability of the drug discovery and development process[(p10)]; discovery of new chemical reactions that will facilitate access to novel molecular structures for lead optimisation; developing more sustainable and integrated processes that deliver transition to scale-up; and development of new, more resilient, and responsive digital manufacturing approaches to facilitate greater integration, accelerating the overall development times.[(p11)] Related to this, GSK is a science-led multinational biopharmaceutical company with a rich heritage in the healthcare industry, operating in >75 markets worldwide with 70 000 global employees, and with >£30 billion group turnover in 2023.[(p12)] Furthermore, GSK was ranked first in the Access to Medicine Index (2022) for the eight consecutive time[(p12),(p13)] and has a strong track record of academic collaboration.[(p4),(p14),(p15),(p16)]

In 2009, as part of a sustained mission of continuous improvement for their drug discovery scientists, GSK, Stevenage looked to establish a unique research and training platform in collaboration with academia. In seeking a potential partner, the University of Strathclyde's understanding of GSK's aims, drivers, and requirements, coupled with individual chemistry academic's research track record and evidence of innovation in industry partnerships, led to them becoming the partner of choice. Furthermore, already existing and fruitful collaborative research interactions between a selection of Strathclyde academics and GSK scientists was also important in underpinning the resulting formal partnership. Aligned with this, GSK associates approached Strathclyde with the intention of maximising knowledge exchange and enhancing scientific excellence specifically through work-based research endeavours, supporting them to remain competitive, innovative, and productive in discovering, developing, and manufacturing new medicines.

This collaboration has now developed into an expansive partnership with over 220 participating postgraduate researchers, which has been transformative in opening unique approaches to research engagement and knowledge exchange while positively influencing the culture and creativity of individual scientists and teams. This review delineates the overarching partnership framework with the aim of also providing a translatable model for the sector. Selected scientific successes and partner benefits of the model are highlighted with specific regard to the PhD studentship programme achievements and deliverables, alongside the additional collaborative research endeavours that the partnership has facilitated.

Programme aims, coverage, and delivery

The original objective within the emerging initiative was to develop a framework that would enable GSK employees to work towards an MPhil or PhD degree through active drug discovery and development projects within GSK laboratories. This involved a careful partnership approach involving Strathclyde's Professional Services and academic colleagues to create a bespoke and robust collaborative agreement that met all key programme aims, while also satisfying University regulations, quality assurance, and governance requirements. Additionally, through rigorous assessment schedules, mechanisms were embedded for academic review of sensitive research data while maintaining all of GSK's intellectual property requirements. Indeed, the terms of the established agreements ensure that all supervisors, researchers, and examiners have access to all aspects of the research data and outputs, with complete transparency. Furthermore, all higher degree theses emerging from the programme are protected via an appropriate moratorium period. With regard to the ownership of intellectual property, for the majority of GSK-based researchers, GSK would own such IP where projects have arisen from ongoing or emerging industrial research endeavours; in a wider sense, any co-creation of new knowledge is attributed as appropriate. The key to success in this overarching domain was that these ventures were specifically designed to accommodate and satisfy both partner's drivers and requirements.

Within each individual research project, dedicated Strathclyde academics work alongside specific GSK scientists to co-supervise postgraduate research projects; academic input regarding emerging scientific knowledge and access to alternative research methods complements GSK expertise in the broad landscape of drug discovery and the provision of state of-the-art facilities and infrastructure. Individual projects are devised and established over a spectrum of approaches and structures, from extensions of ongoing GSK-based research activities through to the co-creation of projects based on a blend of GSK's

BOX 1

Previous GSK employee and collaborative PhD student testimonials

Sebastien Campos, Senior Director, and Head of Medicinal Chemistry, Pharmaron (GSK Employee PhD Researcher 2009–2013)

'The interaction with academia generated by this programme was extremely valuable for GSK projects, bringing enhanced scientific rigour and peer review from highly regarded academics. Indeed, the knowledge exchange between myself, my Industrial Supervisor, and my Academic Supervisor and his research team at Strathclyde were critical to the success of my PhD research studies, which resulted in a patent application and scientific publication in an internationally leading journal.[(p17)]

Undoubtedly, the invaluable scientific and interpersonal skills that I developed within this collaborative programme set the stage for my on-going career. Indeed, following my PhD award, I was promoted to Team Leader within GSK and also held the role of Medicinal Chemistry Leader at the London Francis Crick Institute. During these years, I continued to thrive in my sustained engagement with academia through acting as Industrial Supervisor to a number of new students working towards their higher degrees via the GSK-Strathclyde programmes. In this latter role, I more acutely realised the reach and significance of the partnership, noting that collaborative projects encompassed multiple research themes, as well as a range of disease areas and target families.

Now, as Senior Director at Pharmaron, it is clear that the distinct research training experience provided by this Strathclyde-GSK flagship programme generates researchers with the unique combination of scientific excellence and a business-aligned and -relevant skill set.'

Afjal Miah, GSK Scientific Team Leader (GSK Employee and PhD Researcher 2011–2015)

'My PhD research focused on identifying and optimising novel CCR4 antagonists for therapeutic intervention. Working at GSK, with co-supervision from Strathclyde, I successfully identified four potent inhibitor series, showcasing excellent physiochemical and pharmacokinetic profiles. These outcomes were published as four impactful medicinal chemistry articles.[(p18),(p19),(p20),(p21)]

The training and experience gained form the Strathclyde-GSK PhD collaborative programme was critical for my scientific career progression. Not only did the programme strengthen my organic chemistry knowledge, but it also built my self-confidence to devise strategy and solve challenging medicinal chemistry problems for projects. Since completing the PhD, I have had greater opportunities to lead chemistry projects to key decision points and this has helped me progress my career position to Scientific Team Leader at GSK. I continuously engage with the programme and now supervise a PhD student myself, passing on the skills I have learnt from the collaboration.'

interests and potential impact combined with the expertise and goals of partnering academics. As the projects are initiated and progress, postgraduate researchers benefit from frequent meetings covering both remote and in-person interactions on an approximately monthly basis. As well as this, and based on the sustained length of the programme to date (*vide infra*), appreciable rapport, trust, and understanding has evolved across the academic and industrial supervisory teams, ensuring robust and comprehensive mentorship for individual researchers. Through such coverage, and with each Strathclyde-registered participant being embedded in GSK research teams, a partnership is delivered that reaches beyond the GSK MPhil/PhD candidate chemists to influence and contribute to more expansive organisational learning within GSK. Furthermore, via a series of both scientific and professional development accredited courses embedded within GSK and Strathclyde, all participants have access to a portfolio of structured and assessed learning modules.

Beginning in 2009–2010, with an initial cohort of 20 GSK Stevenage employees in synthetic and medicinal chemistry, the initiative quickly expanded to include analytical chemistry, computational chemistry, drug metabolism and pharmacokinetics, and biological sciences, bringing in a further nine GSK-based postgraduate researchers by the end of 2012, including the first overseas student from a GSK site in the USA. Over the last 12 years, a further 33 researchers have registered on the employee programme (including students from GSK Ware, UK, and Tres Cantos, Spain, as well as a further participant from the USA), bringing the total number of GSK employees to 62. To date, 48 GSK employees have graduated with a higher research degree (7 MPhil and 41 PhD awards), with many going on to more senior positions within GSK or to leading positions within the broader UK pharmaceutical sector. Importantly, all students graduating through the programme are examined against the University's expected standards and assessment pro-

BOX 2

Non-employee 'industrial' PhD student testimonial

Karina Chan, GSK Senior Scientist (GSK Non-Employee and PhD Researcher 2019–2023)

'My experience with GSK and the University of Strathclyde has been exceptionally rewarding for both for my personal and professional development. I have gained excellent knowledge of antibody drug conjugates and proteolysis targeting chimeras (PROTACs), whilst the modules provided by the programme has enabled me to keep up-to-date with chemistry beyond my project. I was also encouraged and supported by many to present my work externally, fostering the dissemination of knowledge, allowing me to engage with the community and ultimately leading to a more fulfilling PhD. I believe working at the interface of chemistry and biology has shaped me into a more interdisciplinary scientist, and the expertise I have gained has facilitated my transition into a full-time role at GSK.'

tocols for the relevant higher degree award. Box 1 highlights testimonials from two GSK employee PhD awardees from the programme; in both cases, the research training experience is specifically acknowledged as underpinning their future career progression.

The collaborative efforts were then further extended beyond the employee-based endeavours in 2012 with the introduction of cohorts of new high-calibre graduates, i.e. nonemployees, to engage in PhD studies within GSK or Strathclyde laboratories. With specific regard to the GSK-based positions, the recruitment of each cohort of researchers takes place collaboratively with involvement of the core Programme Management Team, with applications received from both UK and international candidates. Notably, entry to this industry-based PhD component of the programme has become extremely competitive, with the success rate for securing a position sitting at approximately 5% each year. As part of this new stream of the partnership, the programme was expanded to include further subdisciplines, including chemical biology, process chemistry, and protein–ligand biophysics, as well as an extended collaboration with GSK's global manufacturing and supply sites. Similar co-operative supervision was placed at the core of the model, and the offering of secondments in both directions, into and out of GSK, provides participants with exposure to both academic and industrial settings. From 2012 to 2026, an appreciable pipeline of 220 nonemployee postgraduate researchers in chemistry exists (119 based at GSK and 101 based at Strathclyde), with 107 having already graduated with a higher degree (2 MPhil and 105 PhD awards). It is also notable that a number of nonemployee graduates from the industry-based component of the programme have transitioned into full-time positions within the company following completion of their higher degree research studies (Box 2). Further details on the destinations of graduates are provided in the section on Partner and sector benefits (see later).

The overarching programme has sustained commitment from GSK, which will facilitate the continuation of the partnership until 2030. This also includes the most recent research expansion into the area of biopharmaceuticals, which was initiated in 2021. Indeed, this latter extended collaboration encompasses both the employee and nonemployee models and brings together additional GSK-based research leaders with an expanded array of academic colleagues from Strathclyde, to further develop and support emerging research talent within the GSK laboratories towards both elevated levels of project-related impact and the award of higher research degrees. As part of this key additional development, individual projects have been co-created in areas such as the development of enhanced screening methods to accelerate antibody drug developability; the enhancement of emerging methods in molecular biology and gene expression for the generation of functionally enriched protein systems; the investigation of differing approaches towards the introduction of sequence diversity during antibody discovery; and the development of sequence engineering methods aligned with biophysical sciences and drug administration. It is anticipated that this recently expanded GSK–Strathclyde partnership endeavour will deliver an array of further research outputs in the biopharm area that will underpin the discovery of new therapeutic products, alongside directly supporting the growth of a growing group of GSK researchers with appreciable scientific skill and potential.

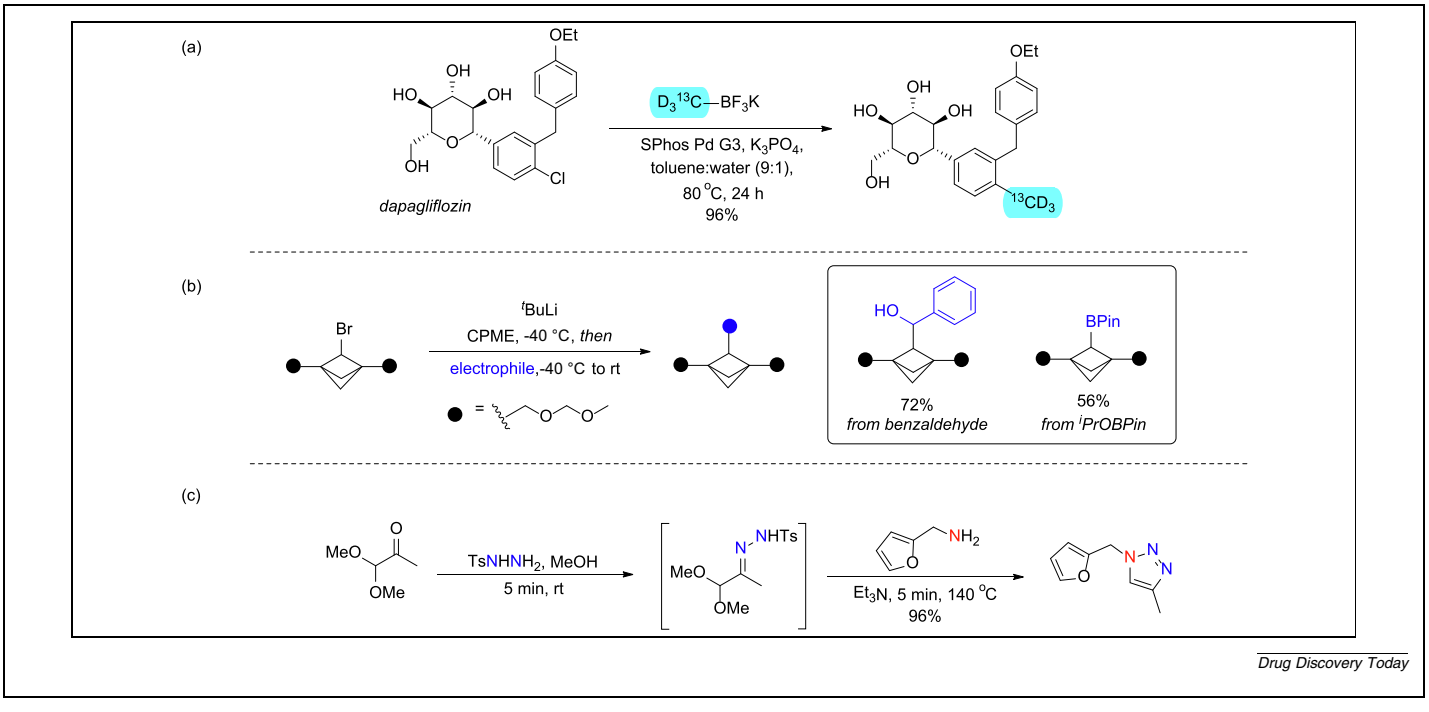

FIGURE 1

Selected key outputs in chemical synthesis: **(a)** late-stage methylation of drug scaffolds to install isotopic labels; **(b)** preparation of bicyclo[1.1.1]pentane (BCP) derivatives; and **(c)** a practically convenient and accessible route towards triazoles.

Scientific and technological outputs

At the core of this partnership is the delivery of new methods that will facilitate access to transformational medicines. Related to this, the strategic relationship between the partners has enhanced the collaborative development of novel and translatable science, allowing distinctive and ambitious initiatives to be more readily adopted, and resulting in the generation of new and essential products and methods being accelerated and streamlined.[p22] For example, in synthesis, a strategy for late-stage carbon and hydrogen isotope introduction has recently been developed,[p23] which represents a key advance towards rapidly assessing pharmaceutical compounds via absorption–distribution–metabolism–excretion–toxicity (ADMET)studies. Specifically, the first use of an isotopically enriched $MeBF_3K$ analogue within cross-coupling chemistry has underpinned the establishment of a robust route to labelled drug-like scaffolds via late-stage methylation (Figure 1a). Importantly, the solid and readily handled BF_3K salt is prepared via a robust and efficient route using nonvolatile intermediates, which is crucial for the translation of these methods into the radiolabelling domain. Moreover, through further collaborative projects, preparative routes to previously less accessible molecular structures have been opened,[p24],[p25],[p26] including, as a selected example, the preparation of bicyclo[1.1.1]pentane (BCP) derivatives (Figure 1b).[p27] Such structures have been realised as unique units

BOX 3

Platform Technologies Discovery Groups

Dr David House, GSK Executive Director, Global Head of Chemical Biology

'Advances in human genetics and scaled deployment of functional genomics in complex disease models is reshaping drug target discovery and validation. Consequently, the opportunity landscape is now less constrained by traditional target classes; innovation in alternative drug modalities has become a strategic imperative to harness this broader target optionality. Reactive fragment screening is one of the ways in which chemical biologists in GSK have sought to exploit alternative modalities to tackle protein targets with unknown or challenging tractability towards small molecules. Advances in mass spectrometry and the advent of direct-to-biology chemistry have enabled the development of a versatile covalent protein screening platform in GSK which has seeded drug discovery programmes for notoriously challenging targets such as transcription factors, ubiquitin ligases, and DNA helicases. This technology is now firmly embedded within GSK's Research Technology organisation and, through our collaborative partnership, continues to evolve with the development of 'beyond-cysteine' targeting chemistries and photo-activatable fragments (PhABits) to provide potential entry points for reversible ligand discovery.'

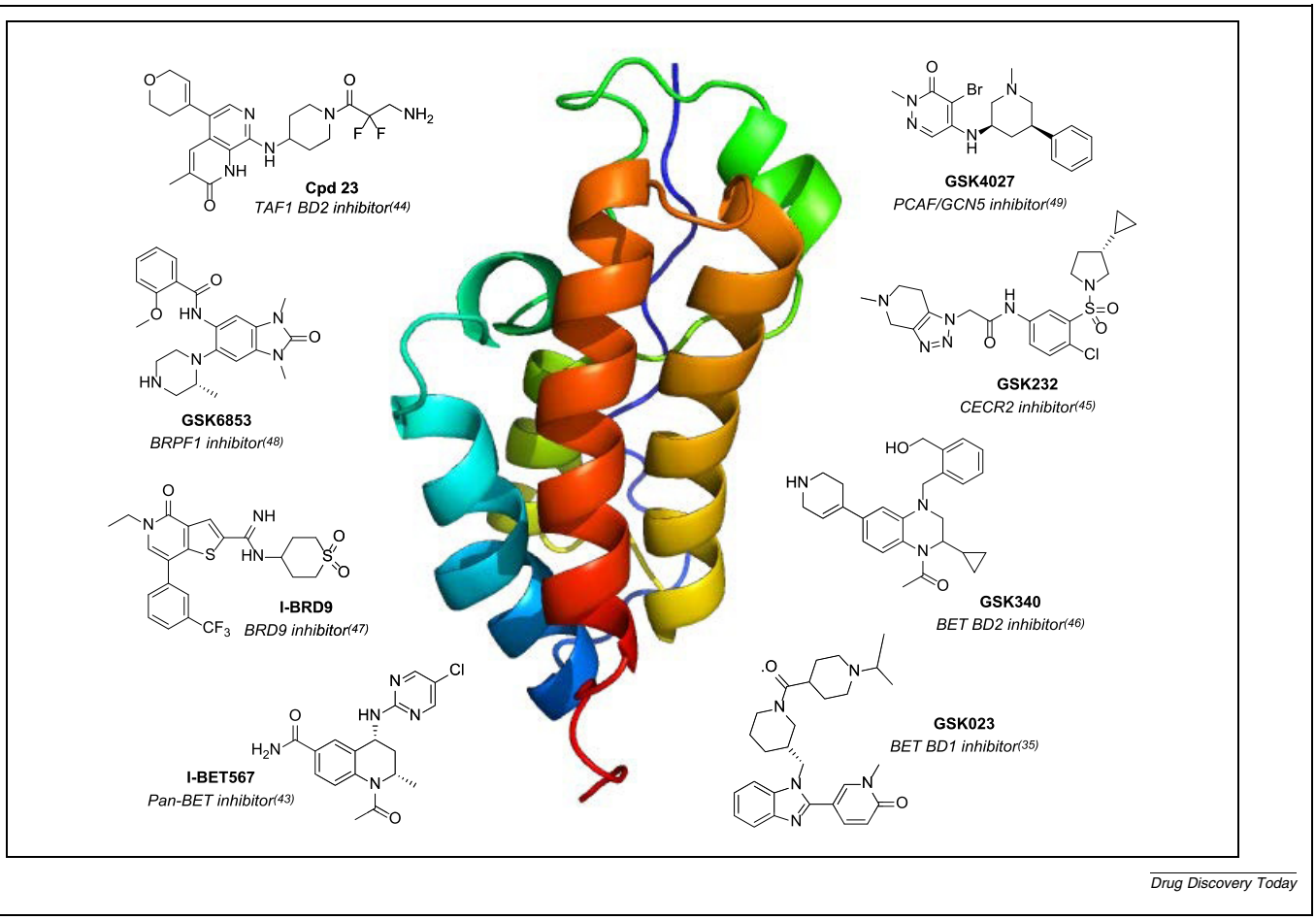

FIGURE 2

Selected bromodomain inhibitors developed as part of the GSK–Strathclyde collaborative programmes and the X-ray crystal structure of apo BRD4 bromodomain 1 (pdb: 2OSS).

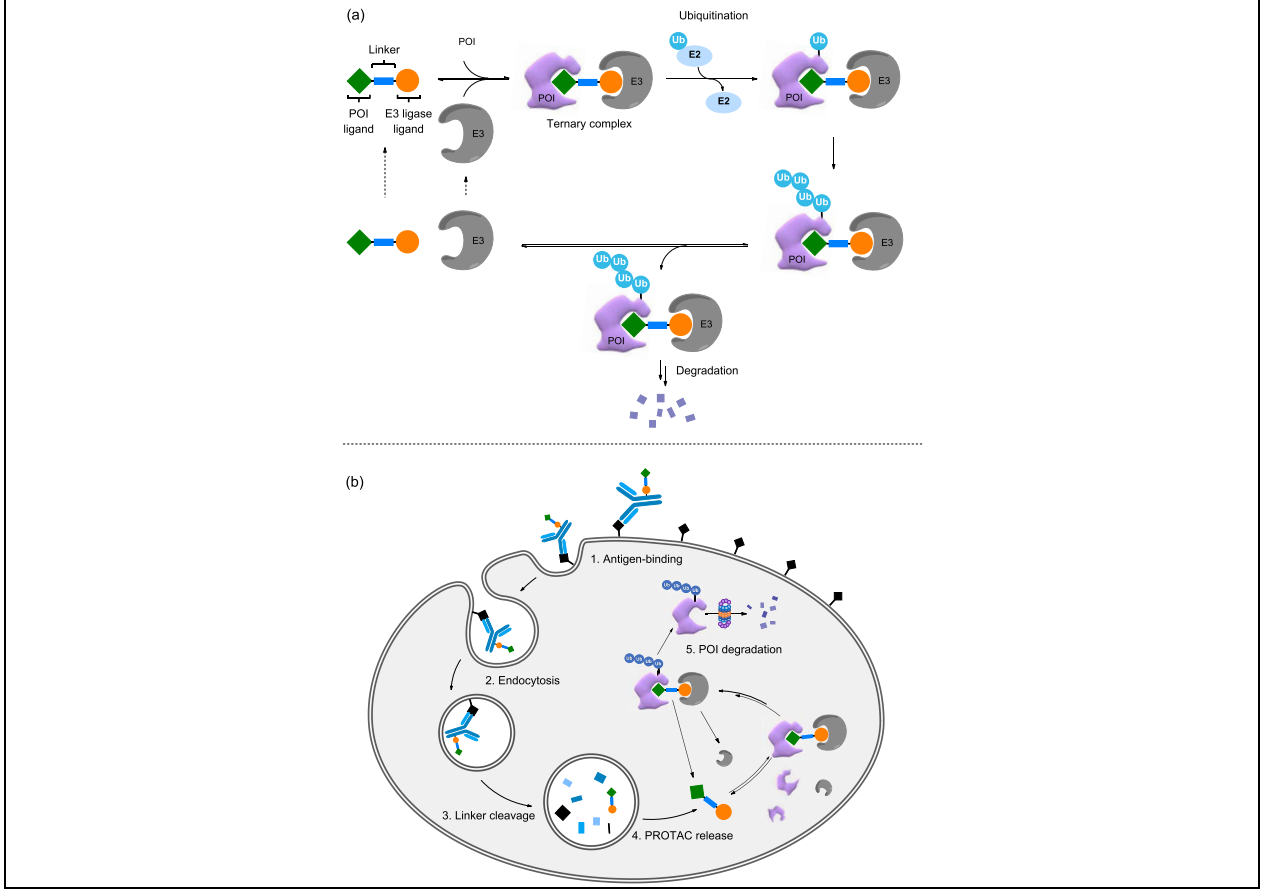

FIGURE 3

Selected PROTAC-based research: **(a)** PROTAC-mediated degradation; and **(b)** antibody-PROTAC conjugates.

to explore novel chemical space, being perceived as bioisosteres of alkynes, *tert*-butyl groups, and arenes, and as associated with improved solubility and metabolic stability. Further, new and more sustainable bench and process-aligned methods have been established,[(p28),(p29),(p30),(p31),(p32)] such as a scalable metal-, azide-, and halogen-free method for the preparation of triazoles (Figure 1c).[(p31)] With respect to theoretical chemistry, including in combination with structural and biophysical analysis, advanced computational methods are guiding the understanding of biochemical systems within several of GSK's drug discovery programmes.[(p33),(p34),(p35),(p36),(p37)]

Considering more classical medicinal chemistry research and development, our collaborative researchers have made significant advances across a number of areas, including in the synthesis and biological evaluation of an array of novel small molecules that engage various targets (including Itk,[(p17)] CCR4,[(p18),(p19),(p20),(p21)] PI3Kδ,[(p38),(p39)] and BCATm[(p40),(p41)]). A specific highlight relates to research towards the design and synthesis of small-molecule bromodomain inhibitors,[(p42),(p43),(p44),(p45),(p46),(p47),(p48),(p49)] which has delivered a series of compound classes with high potency and selectivity towards certain subsets of human bromodomain-containing proteins. Such domains are of substantial biological interest due to their role in modulating gene expression, and inhibitors thereof have progressed into oncology clinical trials.[(p50),(p51),(p52),(p53)] GSK has had a long-standing interest in the therapeutic potential of bromodomain inhibitors, and our postgraduate research programmes have contributed appreciably to the collaborative advancement of these areas within the GSK laboratories (Figure 2). Additionally, several of these inhibitors are now commercially available from Merck via the Structural Genomics Consortium.[(p54)]

In addition to the above, the expanded landscape and scientific expertise from this collaborative partnership has facilitated the foundation, incubation, and growth of GSK's platform chemical biology and antibody–drug conjugate (ADC) discovery groups (Box 3). Within GSK, a number of collaborative postgraduate researchers and their supervisors pioneered and championed the use of reactive fragments as a platform technology to enhance and accelerate early-stage drug discovery.[(p55),(p56)] Based on these key scientific deliverables and advances, the Chemical Biology Department was established within GSK in 2019. This

BOX 4
Advances via direct-to-biology

Direct-to-biology (D2B) has been a truly disruptive innovation and has fundamentally changed the approach to drug discovery at GSK. Specifically, potential drugs can now be discovered more quickly with both the timelines to data generation and the amount of resource required to do so significantly reduced. D2B has impacted projects across a range of important diseases, including castration-resistant prostate cancer, migraine, and tuberculosis. The increased use of automation that is at the core of D2B's success has liberated chemists from routine operations to focus their intellects on more impactful scientific advances. In recognition of the importance of D2B to GSK, a specialised global chemistry group has been built to support, develop, and implement D2B across the research portfolio. This ever-evolving capability is further expanding across other chemistries, multi-step reactions, and assay types to enable multiple assay data generation from a single operation. D2B has also influenced GSK's overarching scientific strategy, whereby every project in GSK's research pipeline is assessed at key internal governance milestones for compatibility with D2B as a key 'speed enabler'.

GSK-based unit has become integral to the identification and validation of new drug targets through chemogenomic and chemoproteomic platforms.

One area of current focus is proteolysis-targeting chimeras (PROTACs), an exciting class of heterobifunctional molecules that enable the selective degradation of a protein of interest (POI) via E3 ubiquitin ligase-catalysed tagging (Figure 3a).[p57],[p58] More specifically, we recently reported the first PROTAC-based strategy towards the degradation of the Janus kinase family (JAK1, JAK2, JAK3, and TYK2) of proximal membrane-bound proteins.[p59] This family of proteins has been implicated in inflammatory diseases and cancer.[p60] As part of this collaborative research project, a series of compounds were designed and optimised, and the mechanism of action was successfully elucidated as being both E3 ubiquitin ligase-mediated as well as proteasome dependent. In a further advancement in this area, to address the cell-selectivity and permeation issues often associated with PROTACs, new collaborative research programmes have aimed to conjugate PROTACs to cell-selective antibodies, thereby generating degrader–antibody conjugates (DACs).[p61] The antibody portion of the DAC acts as a targeting motif to selectively deliver the PROTAC to a specific cell type. This cell-selective delivery therefore allows the PROTAC to carry out targeted protein degradation in those specific cells to drive improved efficacy and the therapeutic index (Figure 3b). In this regard, cell-targeted delivery of a cathepsin-cleavable RIPK2 PROTAC to HER2+ SKOV3 cells was achieved, resulting in RIPK2 protein degradation. This important proof of concept provides a key design strategy complementary to more traditional small-molecule cytotoxic payload ADCs.

A clear highlight of the partnership has been the direct connection with the development of direct-to-biology (D2B) chemistry approaches within GSK, which exemplifies an innovative disruption of the traditional drug discovery process (Box 4). Through the novel combination of an automated ultrahigh-throughput synthesis platform and the direct biological testing of unpurified reaction mixtures, D2B has brought a step change in how GSK carries out drug discovery. Notably, the proof of concept for this approach within GSK was delivered by a collaborative University of Strathclyde–GSK PhD researcher, and the approach has been further refined and escalated by several additional such GSK-based postgraduates working in global discovery high-throughput chemistry, chemical biology, and modalities platform technologies research groups.[p62],[p63],[p64],[p65] This approach has led to further discoveries allowing the accommodation of different synthetic chemistries to expand the accessible chemical space, as well as the types of biological, pharmacokinetic, and physicochemical assays that are applicable to unpurified reaction products.

BOX 5
Scottish parliamentary motion S3M-05519

'... the Parliament congratulates the University of Strathclyde and ... GSK on the first ever initiative in the UK to deliver a bespoke postgraduate ... chemistry degree programme; recognises that this unique research programme will be geared towards identifying and developing novel treatments for a range of diseases; ... acknowledges the potential that this will have to deliver considerable benefits for patients and public health; commends this innovative initiative as a tangible demonstration of the benefits of collaboration ... between academia and industry, and notes that the programme ... aims to benefit society as a whole.'

Recognition and successes

Since its inception, the collaborative GSK–University of Strathclyde doctoral research and training partnership has been recognised and commended on several occasions. In 2010, the emerging and initial MPhil/PhD employee programme was the subject of a Scottish Parliamentary motion on the establishment and initial delivery of this bespoke endeavour (Box 5).[p66] As part of this recognition, the programme was commended by the, then, Scottish Health Secretary and Deputy First Minister as being a particularly notable partnership for Scotland. Our collaborative non-employee programme component was also highlighted as an exemplar Case Study in Sir Tim Wilson's Review of Business-University Collaboration (commissioned by the UK government).[p67] In 2014, our collaborative initiatives were highlighted as a further case study in the strategically important life sciences sector within the Universities UK (UUK) and the UK Commission for Employment and Skills (UKCES) report 'Forging Futures: Building higher level skills through university and employer collaboration'.[p68] The joint report shows how universities and employers are working together to create a new generation of highly skilled workers, building key partnerships, and tailoring courses to produce individuals with the skills needed

BOX 6

Dave Allen, GSK Senior Vice-President and Global Chief Chemist

'Our rich array of pharma-aligned PhD studentships has resulted from a series of sustained and reciprocally beneficial relationships over a large number of years, and has specifically enhanced the exchange of new science to and from the pharma industry, allowing distinctive and ambitious initiatives to be more readily implemented and delivered. Through broad collaborative engagements across GSK, a distinct and unique research and training programme has been built, which delivers sustainable impact within our national capabilities at GSK, whilst also generating a pipeline of industry-ready scientific personnel for the wider external pharmaceutically-aligned and related scientific sectors.'

by their sector. Furthermore, the Strathclyde–GSK collaborations have been prominently highlighted in three successive Association of the British Pharmaceutical Industry (ABPI) publications (2016,[(p69)] 2019,[(p70)] and 2022[(p71)]), illustrating the impact of this programme on the national standing of the University of Strathclyde in relation to pharmaceutical industry collaborative research studentships.

Underpinning the successful higher degree awards is an array of high-quality research outputs, publications, and student (and programme) accolades and awards. To date, more than 160 collaborative peer-reviewed research papers have been published,[(p22)] and our researchers have been the recipients of >200 individual student prizes. Notable student awards include the highly prestigious international Reaxys Prize, which celebrates the very best chemistry research being performed on a global scale; the Salter's Centenary Award, which recognises those very top individuals deemed to have the potential to make outstanding long-term contributions to industries; the Royal Society of Chemistry (RSC) Young Industrialist of the Year 2015; multiple Society of Chemical Industry (SCI) Young Chemist in Industry Awards; and, most recently, seven winners of an SCI Scholarship Award and six winners of an 1851 Royal Commission Industrial Fellowship. All such awards are an indication of the calibre of researchers engaged in on our programmes, as well as markers of the quality of the combined academic and industrial supervision, and associated research programmes.

The programme itself has also been the recipient of >15 individual awards or accolades, including the Royal Society of Chemistry's 2021 Industry-Academia Collaboration Award as well as contributing prominently to GSK's two Princess Royal Training Awards in 2019 and 2022.

Partner and sector benefits

Business benefits have become increasingly evident as this collaboration has progressed. A core impact has been the perceived escalation of research excellence with the enhanced skills, scientific rigour, creativity, and productivity displayed by GSK staff. With regard to researcher training and development, the partnership is firmly recognised as a landmark programme for the devel-

BOX 7

Phil Humphreys, GSK Senior Director, Discovery Chemistry Europe Lead (GSK Industrial Supervisor, 2011–2019)

'Supervising PhD students as an industrial supervisor and collaborating with academics at the University of Strathclyde has had a profound impact on my career. I have been afforded numerous opportunities due to my involvement in the programme, including being appointed to the Chemicalprobes.org Scientific Expert Review Panel, being appointed as a GSK Senior Fellow, and presenting at international conferences. This has built my internal and external reputation, as well as expanding my professional network. The programme has also developed my scientific thinking, communication and writing styles. As an industrial supervisor, I have had the privilege to support, mentor, and coach several talented students which has developed my leadership skills substantially. Collaborating with academics at the University of Strathclyde has also been a rewarding experience, with a particular highlight being the ten papers I have co-authored with Prof. Nick Tomkinson at Strathclyde.

In my role as Discovery Chemistry Europe Lead, I see the programme as a cornerstone of the development of our scientific staff at GSK. Whether taking part in the programme as a student, or guiding students as an industrial supervisor, the opportunity for scientific and personal growth is unparalleled at GSK.

The focused critical mass of students on the programme allows both parties to innovate and develop tools and technologies that directly impact drug discovery (e.g. D2B, chemical probes). The annual nature of students joining the programme also allows pivoting to new areas of science, allowing GSK to move quickly to explore and incubate as appropriate (e.g. ADCs). As we explore the ever-changing landscape and opportunities in cutting edge drug discovery, this flexibility is invaluable.'

James Thompson, GSK Medicinal Chemistry Team Leader (collaborative PhD student, 2016–2020; Industrial Supervisor, 2022–)

'I was initially drawn to apply to the collaborative PhD programme out of a desire to work on chemistry research that was directly applicable to drug discovery efforts and benefitting patients, as well as wanting to simultaneously understand whether I would be interested in a career in industry after my PhD studies.

The highly interdisciplinary nature of my PhD research (interfacing with analytical and computational chemistry, biological screening, and DMPK groups) was invaluable preparation for my career in industry that has ensued since. Following my PhD award, I was directly employed by GSK and have since been promoted to Team Leader. I continue to benefit via the role of Industrial Supervisor of a current collaborative student, using my insight as a previous programme participant to nurture the development of their synthetic, scientific, and wider professional skillset. Additionally, making decisions in the direction of the research has also enabled me to grow in my ability to think strategically, which continues to serve me in my career. Working closely with the Strathclyde Academic co-supervisor (now as a peer) has also enabled me to learn from their experience and understand their research priorities more clearly.'

opment of early talent and is central to GSK strategy and policy within the associated research areas. GSK staff have developed alternative solutions to drug discovery and development issues, have sought opportunities to communicate their work within and beyond the company, and are more expansively engaged with the wider scientific community. For example, it has been recognised that employee MPhil and PhD researchers generally increased their contribution to the scientific literature approximately fivefold from the period before they were enrolled on the programme. Related to this, Dave Allen, GSK Senior Vice-President, describes the passion and vision shared between Strathclyde and GSK for extending scientific development and growth for chemists at all levels (Box 6).

To date, over 160 GSK employees (62 as students and >100 as industrial supervisors) have benefitted directly from engagement with the partnership programme. The prominence of this initiative within GSK is evident when considering the progression of the students throughout the organisation to more senior roles, where historically it was noted that such graduates did not readily advance. Related to this, in 2014, a new Department of Chemistry was initiated at GSK, requiring senior leaders, graduates, and postdoctoral chemists. Notably, four of the five newly appointed senior team leaders were employee graduates of the PhD programme. These successes have since escalated, with a further nine employee graduates having been elevated to managerial positions. Furthermore, there is prominent internal recognition of the GSK industrial supervisors within the programme, with Dr Philip Humphreys (now Senior Director) having been awarded GSK's Future Leader Programme Line Management Award in 2017 (Box 7).

The philosophy adopted through the collaborative programmes is consistent with evolving thought leadership within the pharma industry,[p1] demonstrating GSK's position at the forefront of approaches to improve the efficiency and effectiveness of industry-based drug discovery and culture. The programmes have also had a positive and tangible impact on GSK's reputation as an employer, as evidenced by, for example, the 100% increase in applications to the company's 2014 recruitment campaign in comparison to that held a few years earlier. GSK's enhanced reputation as an employer is further exemplified by GSK Chemistry receiving the Learning and Development Award at the 2020 Personnel Today Awards, as well as GSK's Chemistry Continuous Professional Development Programme being the recipient of the In-house Team Award at the inaugural 2021 Learning Excellence Awards.

In relation to the benefits to the university, Strathclyde has realised appreciable knowledge exchange enhancement through being so directly connected with and exposed to approaches, techniques, and cultural/corporate values within the pharmaceutical industry, which directly informs and impacts upon the development of undergraduate and postgraduate student training. Additionally, the combination of expertise and development of close collaborative relationships catalyses and delivers further distinctive and ambitious research initiatives that flow in both directions. The existing framework also allows Strathclyde academics to escalate individual research partnerships, with additional projects often flowing out of GSK and into Strathclyde laboratories, and with the GSK industrial collaboration continuing (*vide infra*). Overall, Strathclyde is committed to delivering an outstanding student experience, and the Strathclyde–GSK part-

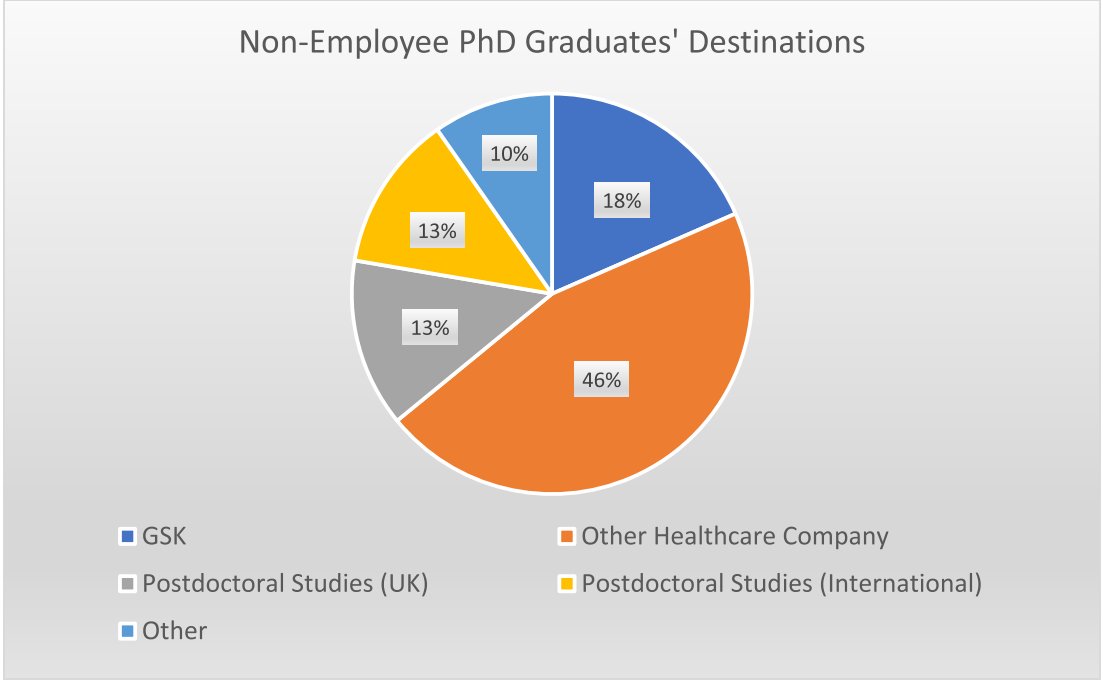

FIGURE 4
Non-employee PhD graduate destinations.

BOX 8

Charlotte Hardy, Director of Chemistry, Charles River Laboratories

'We are now reaping the benefits with a number of alumni now current or past employees of our company, including myself as Director of Chemistry. Such colleagues are now delivering notably elevated impact within our laboratories. They have, on several occasions, overcome significant synthetic chemistry challenges to deliver appreciably complex molecules for our client drug discovery programmes. Additionally, they have also contributed to the design of novel drug-like molecules, actively and strategically embedding their developed new skills, such as computational modelling, to do so. I firmly believe that the established Strathclyde-GSK higher degree programmes are delivering tangible impact across the sector.'

nership provides a blended research endeavour of clear and considerable value to all students, whilst assisting in the creation of a diverse and vibrant student population.

To achieve and deliver these programme benefits, a number of key elements should be considered and implemented. Importantly, academic partners should position themselves to work quickly and responsively with the external partners. Related to this, openness, flexibility, and trust are key components of such intensive collaborative relationships; thus, supervisors and senior leadership across both main parties committed to such an ethos will enable continual positive partnership operation, as well as the identification of further collaborative opportunities of mutual benefit. Additionally, as any programme grows, consistent coordination and management is crucial, alongside prominent and committed leadership. Indeed, the Strathclyde–GSK programme is robustly governed through two programme directors (one Strathclyde- and one GSK-aligned), as well as a Strathclyde-based research programme manager, all of whom are critical to the success and operation of the overall collaborative partnership.

In the broadest sense, the programme has developed and delivered research professionals with elevated levels of training, skill, and learning agility. The complementary expertise from each partner has maximised innovation, catalysing research fundamental to the generation of new and essential healthcare products while also positively influencing the culture and creativity of individual scientists and teams. This benefits not only GSK but also the wider healthcare sector, across the UK and internationally, as the graduates are academia- and industry-ready, and possess the attributes necessary to lead in the global workplace. Indeed, the non-employee graduates emerging from our collaborative endeavours have secured competitively won UK, European, and global industrial and academic positions, with many having been actively recruited by an array of national and international pharmaceutical organisations such as AstraZeneca, MSD, Heptares, Charles River Laboratories, Astex, Cancer Research UK, Evotec, Pharmaron, and Reckitt Benckiser (Figure 4). These individuals are having a significant influence on R&D programmes within these companies, with an example provided in Box 8.

Enabling additional funding initiatives

Beyond the core partnership itself, the GSK–Strathclyde partnership has also catalysed additional, externally funded, collaborative research initiatives. As directly related to this, further funding streams have been accessed that would have been unavailable without such an existing (large-scale) partnership and support. Specifically, two recent UKRI Prosperity Partnership

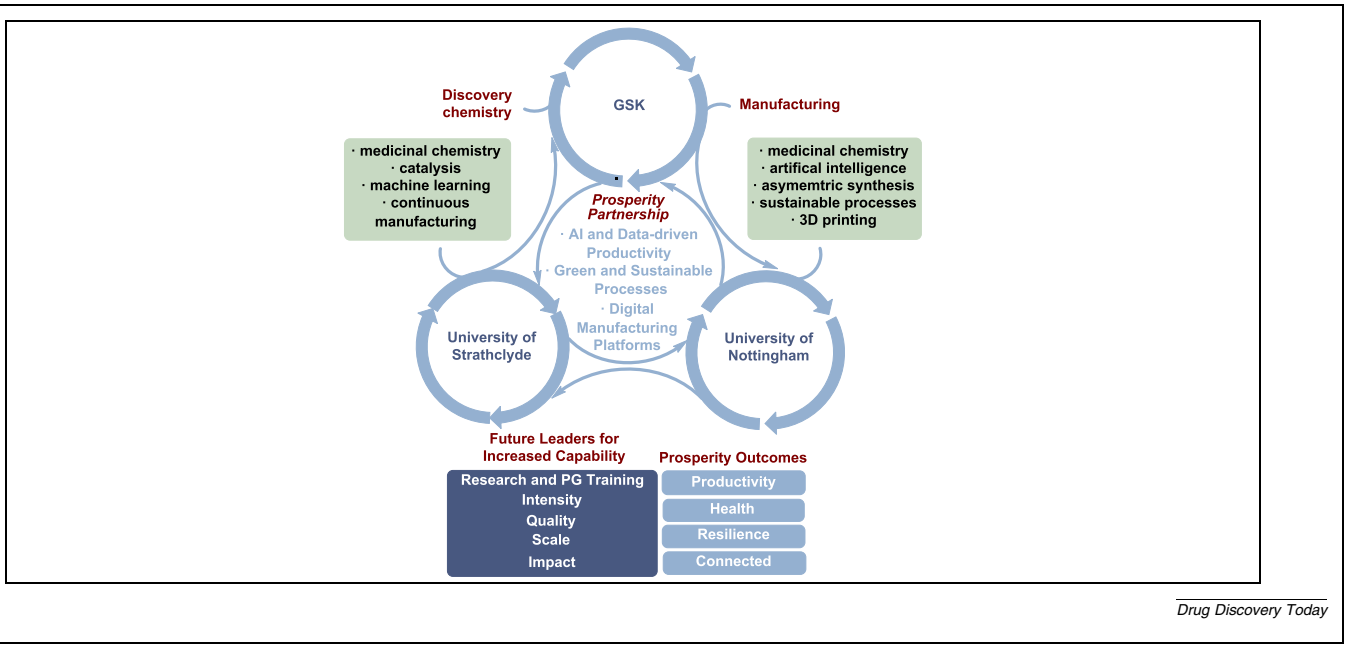

FIGURE 5

Overarching structure of the Strathclyde/Nottingham/GSK EPSRC Prosperity Partnership.

grants have been awarded to Strathclyde and GSK by the Engineering & Physical Sciences Research Council (EPSRC) (£5.6 million, with the University of Nottingham as an equal partner) and the Biotechnology and Biological Sciences Research Council (BBSRC) (£2.66 million). Such high-value UK government-supported research grants have significant benefits for the partnering businesses, acting to de-risk involvement in new fundamental research activities that have the potential for an appreciably high return. With research projects co-created by the academic and business partners, such funding support facilitates GSK's direct involvement with research aligned with business at the very early stages of knowledge creation.

In addition to the GSK–Strathclyde collaborative partnership, the EPSRC Prosperity Partnership programme was further underpinned by extensive and sustained research and training partnerships between GSK and the University of Nottingham.[(p72),(p73)] Figure 5 delineates the various themes of this EPSRC Prosperity Partnership, which span the drug development continuum from discovery to manufacturing and are underpinned by the twin paradigms of applying data-driven approaches and embedding sustainable methods across all themes. The overall partnership has supported a total of 14 postdoctoral positions, with the cohort of researchers leading scientifically novel projects with the distinct additional aim of application to solve business-critical challenges within GSK, and with direct benefit to the wider pharmaceutical industry. Notably, the nature of UKRI's Prosperity Partnership funding model has allowed flexibility within the scientific projects, enabling the joint academic–industrial teams to realign the supported research studies with new end applications as business priorities changed during the course of the programme. For example, the Prosperity Partnership model allowed the digital manufacturing theme to rapidly pivot their emerging platform to a new business area, with support from the Partnership's external advisory board. Additionally, this EPSRC Prosperity Partnership programme has also developed a further cadre of emerging research leadership personnel possessing direct insights into and knowledge of the demands and drivers within an internationally leading pharma environment.

Concluding remarks

Through the sustained investment since 2009 of over £20 million into the University of Strathclyde–GSK collaborative partnership, the continuing programme aim is to support and facilitate the delivery of innovative medicines across GSK's research and development portfolio. Overall, the partnership has extensively raised training standards and led to enhanced researcher performance, productivity, rigour, and creativity from the scientists involved, all while driving the translation of new science from academia into industry and vice versa, as well as leading to broader benefits for the wider healthcare sector with eventual downstream positive impacts on public health. The innovation-aligned research and training impact of a collaboration of this scale has been significant and extensive, with selected examples delineated throughout this review. This programme highlights a unique academia–industry collaborative model with sustained success over 15 years, and provides a scalable and translatable framework with the capacity to make a major contribution to the UK scientific talent base by creating a pipeline of newly qualified, highly talented, academia- and industry-ready higher degree graduates.

CRediT authorship contribution statement

Laura C. Paterson: Writing – original draft, Project administration, Methodology. **Philip G. Humphreys:** Writing – original draft, Supervision, Methodology, Investigation, Formal analysis, Data curation. **Henry A. Kelly:** Writing – review & editing, Visualization, Resources, Project administration, Funding acquisition, Formal analysis, Data curation, Conceptualization. **William J. Kerr:** Writing – review & editing, Visualization, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Data availability

Data will be made available on request.

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Declarations of interest

The authors declare no conflicts of interest.

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