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Purposeful Physics Enrichment Evidence Review

April 2026

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Table of contents

Table of contents ***2***

Acknowledgements ***4***

About the authors **4**

Foreword ***5***

Executive summary ***6***

Recommendations ***8***

How these recommendations were developed 8
For schools and colleges 8
For funders 9
For policy makers and wider sector 10

1. Introduction ***11***

1.1 Purpose of the review 11
1.2 Socio-economic background and participation in physics 12
1.3 Defining purposeful physics enrichment 12
1.4 Policy and practice context 12

References **13**

2. Methodology ***14***

2.1 Search strategy 14
2.2 Limitations 15
2.3 Eligibility criteria 16
Inclusion criteria 16
Exclusion criteria 16

References **16**

3. Conceptual and theoretical frameworks ***17***

3.1 Science capital 17
3.2 Socio-economic disadvantage and participation 17
3.3 Enrichment type definitions 18
3.4 Analytical approach 19

References **20**

4. Findings from the literature ***21***

Robustness 21
Breadth 21
Science capital impact 21
4.1 Careers-related activities 22
4.2 Competitions 23
4.3 Family learning events 25
4.4 Mentoring 26
4.5 Multi-school events 27

4.6 Projects 27
4.7 Residentials 28
4.8 Role models 29
4.9 STEM clubs 31
4.10 Visits and trips 32
4.11 Workshops 33
4.12 Multiple engagement and sustained provision in physics enrichment 35
4.13 Cumulative impact over time 36
4.14 Focus on socio-economic disadvantage 36
Absence of evidence 36
Careers 37
Family events 37
Multi-school events 37
Projects 37
Residentials 37
Role models 37
Workshops 38

5. Conclusions 39

5.1 Summary of what works for physics enrichment 39
5.2 Evidence gaps and areas for further research 39
5.3 Opportunities to lead purposeful enrichment practice 40
5.4 Drawing up recommendations 40

References 41

Careers-related activities 41
Competitions 42
Family events 42
Mentoring 42
Multi-school events 42
Projects 43
Residentials 43
Role models 43
STEM clubs 44
Visits and trips 45
Workshops 45

Acknowledgements

We are very grateful to Dr Jenny Search (The Impact Co-Lab) for her assistance with the research and her thorough comments on numerous drafts. Professor Heather King (King's College London) provided invaluable guidance, both on the methodology and through her comments on draft versions of the report. We are also thankful to Dr Richard Brock (King's College London) for his guidance on the research approach and his feedback on several drafts. We would like to thank the teachers and numerous outreach professionals whose insightful comments helped us frame the findings of this report. We are grateful for the support of The Ogden Trust, in particular, Elizabeth Gold, Kirstin Greygoose, Amanda Poole and Clare Harvey, whose guidance throughout the project has been invaluable in shaping its direction. Any errors or omissions remain our own. The views expressed in this report are those of the authors and do not necessarily reflect those of The Ogden Trust.

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Foreword

Increasing access to purposeful enrichment opportunities showcasing physics pathways for young people is one of our five key objectives for 2026-2031. We know that taking physics beyond the classroom is a fundamental factor in shifting attitudes towards physics and raising aspirations – but how do you ensure that enrichment is meaningful, equitable and sustainable?

For the past 15 years, we have been providing support for primary and secondary schools so they can offer school-based physics enrichment activities and we have seen – through evidence and experience – that some activities appear to have greater impact than others.

As workload and financial pressures on schools continue to grow, establishing and delivering meaningful, purposeful enrichment can feel like a step too far for busy teachers. But with schools set to be judged on enrichment benchmarks, the need for practical, purposeful enrichment programmes is increasingly important.

This review has looked at eleven popular enrichment activities and considers what works well and what is less effective. It gives particular consideration for how activities reach and engage socio-economically disadvantaged pupils who are often most disenfranchised from physics and the opportunities it can underpin.

The recommendations in this review provide a valuable, evidence-informed head start to school staff who are planning to introduce effective physics enrichment programmes, and make actionable suggestions for funders, policy makers and the wider sector.

Clare Harvey
Chief Executive

Executive summary

Physics is central to the UK's scientific and economic future, yet participation remains uneven, with persistent gaps by socio-economic background, gender and geography. Students from socio-economically disadvantaged backgrounds are consistently less likely to continue with physics in post-16 education, regardless of the qualification route taken. High-quality STEM enrichment can help by building the skills and science capital, complementing formal classroom learning and widening access to opportunities. However, enrichment takes many forms, and its design and effectiveness vary considerably.

This review synthesises UK evidence on physics-related enrichment for school-aged students, drawing on 121 studies and reports identified through academic databases, grey literature and reference searches. Using a science capital framework, it examines 11 types of enrichment activity and maps reported outcomes to four domains: what young people know about science, how they think about it, what they do with it, and who they know in science-related fields (Table 1).

Overall, the evidence suggests that enrichment can build science capital, particularly when provision is sustained, combines multiple approaches, and is embedded within collaborative partnerships between schools and enrichment providers. Mentoring shows the clearest positive impacts across all four science capital domains. Project-based enrichment, careers activities with employer contact, and role model interventions each demonstrate impacts in two or more domains. Residential programmes and STEM clubs can build engagement and confidence, though their reach and sustainability vary. Workshops are the most frequently evaluated activity type but have the weakest overall evidence strength, often relying on short-term, self-reported outcomes.

The strongest evidence points to sustained, multi-component programmes that combine curriculum-aligned activity, hands-on investigation, role model engagement and career awareness over extended periods. While one-off provision is often positively received, evidence of lasting impact is limited. For students from socio-economically disadvantaged backgrounds, some programmes show encouraging findings—most notably, CREST Silver participants eligible for free school meals achieved two-thirds of a GCSE grade higher in science, and an Isaac Physics residential eliminated knowledge gaps by socio-economic status for covered material. However, most evaluations do not report outcomes separately by background, making it difficult to draw firm conclusions about gap-narrowing. Few studies track long-term outcomes beyond immediate post-activity measures, and the 'who you know' domain receives limited direct measurement. Competition-based enrichment raises equity concerns, with participation concentrated among already motivated and less disadvantaged students.

Across activity types, there is scope for strengthening evaluation approaches, including longer-term follow-up.

On this basis, the review provides evidence-informed recommendations for funders, school and college leaders, classroom teachers and policy makers, aimed at supporting more purposeful, equitable and effective physics enrichment across the UK. A summary of evidence and recommendations by activity type is provided in Table 1, with detailed findings in Section 4.

Table 1: Summary of evidence and recommendations by activity type. Note: This table provides a high-level overview. Detailed evidence and discussion for each activity type is presented in Section 4.

Activity type	**Evidence strength**	**Evidence breadth**	**Overall science capital impact**				**Key recommendations**
			Who you know	**How you think**	**What you do**	**What you know**	
Careers-related activities	Moderate	Broad	✓	✓			Combine hands-on tasks with career route information and employer/role model engagement
Competitions	Weak	Narrow		✓	✓	✓	Complement with broader access strategies; monitor equity of participation
Family events	Moderate	Narrow		✓	✓	✓	Adopt sustained partnership approaches; design activities families can continue at home
Mentoring	Moderate	Medium	✓	✓	✓	✓	Ensure sustained engagement with relatable role models; use discussion-led approaches
Multi-school events	Moderate	Narrow		✓			Build in explicit career messaging and follow-up activities
Projects	Moderate	Broad		✓	✓		Provide sustained ownership with mentor/industry links and clear completion routes
Residentials	Moderate	Narrow		✓	✓		Target recruitment to ensure disadvantaged students can access opportunities
Role models	**Moderate**	**Broad**	✓	✓	✓		Feature relatable professionals embedded within hands-on activities
STEM clubs	Moderate	Broad		✓	✓		Deliver consistently; incorporate authentic scientific practice
Visits and trips	Moderate	Medium		✓		✓	Align with curriculum; prepare beforehand; engage families
Workshops	Weak	Broad		✓	✓	✓	Pair hands-on investigation with curriculum links and role models; sequence sessions

Recommendations

How these recommendations were developed

The following recommendations are derived from two complementary strands of synthesis presented in this review. First, evidence relating to each of the eleven enrichment types was evaluated in terms of both its strength (methodological robustness) and breadth (volume of studies) and systematically mapped against the four science capital domains (see Table 1 and Section 4). This analysis provides an evidence-informed account of the specific contributions that different forms of enrichment can make to the development of students' science capital.

Second, cross-cutting themes identified across the literature, including the importance of sustained engagement, multi-component programme design, partnership working, access to role models and equity of access, were synthesised to characterise the features of effective enrichment more broadly (see Sections 4.12–4.14 and 5.1).

The recommendations presented below integrate these two perspectives, combining activity-specific evidence with wider insights into the design principles that underpin purposeful physics enrichment.

For schools and colleges

1. **Designing purposeful enrichment activities**
    a. Prioritise sustained, multi-component interventions over one-off events.
    b. Combine hands-on activities, role model engagement, career awareness with curriculum alignment.
    c. Incorporate authentic scientific practice through partnerships with researchers, industry professionals, or access to real data and equipment.
    d. Ensure physics enrichment activities include diverse and relatable role models, enabling a wider range of students to recognise connections between physics and their own identities, experiences and possible futures.
    e. Design activities that explicitly connect physics concepts to real-world contexts and career pathways, making routes into physics clearer and more accessible.

2. **Embedding equity considerations**
    a. Monitor who attends enrichment activities to identify and address barriers faced by underrepresented groups.
    b. Avoid competition-based enrichment as the sole model, as participation is typically dominated by already motivated students.
    c. For visits, prepare beforehand and engage families to ensure enrichment activities are accessible to students with varying levels of science capital.
    d. Consider multimodal delivery (hands-on, visual, digital) and higher staff ratios to support students with SEND.
3. **Monitoring and evaluating impact**
    a. Collect baseline and follow-up data on student attitudes, career awareness, and subject intentions, explicitly reporting comparison data for disadvantaged groups.
    b. Track participation rates and completion across enrichment activities to identify implementation barriers and inform improvement.
    c. Work with enrichment providers and funders to evaluate programmes to aid sector-wide learning about what works.

For funders

1. **Supporting sustainable partnerships**
    a. Fund multi-year programmes rather than one-off initiatives, building relationships with schools and colleges, and between schools, colleges, universities, and industry partners.
    b. Support the infrastructure for sustainable, high-quality delivery, including volunteer training, teacher professional development, and co-ordination capacity.
    c. Invest in enrichment models that integrate multiple intervention types (e.g., mentoring, workshops, projects, careers) rather than isolated activities.
    d. Align enrichment funding cycles with school planning timelines to enable integration into curriculum delivery and progression pathways.
2. **Reducing barriers to participation in physics enrichment**
    a. Require applicants to explain their strategies for recruiting and retaining students from socio-economically disadvantaged backgrounds, with clear strategies for recruitment and retention of students from these backgrounds.
    b. Prioritise funding for interventions with demonstrated effectiveness for students from disadvantaged backgrounds, such as project-based enrichment with mentoring and scaffolding.
    c. Support programmes that address barriers to participation, including transport costs, equipment provision, and low science capital (for example, family engagement).

3. **Strategic priorities**
    a. Commission rigorous, longitudinal evaluations of enrichment approaches with matched comparison groups and which report outcomes for disadvantaged groups.
    b. Fund research examining mechanisms of impact, including how different components of multi-strand interventions interact and contribute to outcomes.
    c. Support sector co-ordination to share or publish evaluation findings, effective practice models, and lessons learned across the enrichment landscape.

For policy makers and wider sector

1. **Integration with STEM education policy**
    a. Recognise enrichment as a central component of physics education rather than an add-on, particularly for building science capital.
    b. Create policy frameworks that value broader science capital impacts when evaluating intervention effectiveness.
2. **Strengthening access to physics enrichment opportunities**
    a. Address accountability pressures that limit teachers' capacity to deliver informal physics learning, recognising enrichment's contribution to long-term subject uptake and career pathways.
    b. Support equitable access to enrichment across geographic areas, ensuring communities in the most disadvantaged areas receive proportionate provision and resources.
    c. Develop quality standards for physics enrichment that emphasise equity, inclusion, curriculum alignment, and evidence-based practice, supporting schools to make informed provider selections.
    d. Track student progression from enrichment participation through qualification choices to career pathways, assessing long-term impact.

1. Introduction

1.1 Purpose of the review

Physics underpins the UK's scientific, technological and economic future, yet participation remains uneven. The ASPIRES 3 report shows lower post-16 uptake than other sciences, continued male dominance, and higher participation among more socially advantaged students, with gaps emerging early and widening over time. It is worth noting, however, that disability and other intersectional aspects of science capital were not explicitly examined in the ASPIRES dataset.[1] These patterns reflect unequal access to specialist teaching, resources and enrichment, compounded by geographic disparities, with fewer opportunities in many coastal, rural and former-industrial communities.[2]

Enrichment activities, such as workshops, projects, STEM clubs and encounters with physicists, are widely used to support engagement and progression. Alongside formal teaching, high-quality enrichment can play an important role in developing practical skills, confidence and broader capabilities such as teamwork and problem-solving, which are associated with progression in education and employment.[3] However, one study states that while over 40% of (astro)physics undergraduates report attending outreach enrichment activities, nearly 60% did not engage due to lack of awareness or school barriers,[4] highlighting inequalities in access to physics enrichment.

National survey data illustrates both the reach and limitations of STEM enrichment. Hamlyn et al. found that 43% (n=7,256) of secondary school aged students had taken part in at least one school-based STEM activity, most commonly talks, clubs and careers events.[5] Participation was strongly linked to family STEM connections (57% for those with many connections, compared with 26% for those with none), and varied by age and location, with higher engagement in London and among younger students. Participation was also associated with existing aspirations: 88% of participants reported interest in a STEM career, compared with 69% of non-participants in STEM enrichment. Activities most likely to encourage continued study in STEM were found to involve working with specialists and extended projects, which reached very few students (4-8%), suggesting that the most impactful experiences are often likely to be the least accessible, particularly for those without existing STEM networks. Additionally, access to STEM clubs such as robotics clubs has been found to be unequal by school type, with 56% of independent schools offering them compared to just 31% of state schools, indicating a resource-driven disparity.[6]

1.2 Socio-economic background and participation in physics

Socio-economic status is one of the strongest predictors of physics progression and physics shows the largest disadvantage gap across STEM subjects, with high-achieving disadvantaged students less likely to progress to A-level despite similar GCSE outcomes.[7] Disadvantage shapes participation through access to specialist teachers, enrichment opportunities, and family higher education experience. Unequal access to inclusive STEM experiences can limit opportunities for some students to develop science capital and shape their STEM identities, with implications for participation and, ultimately, the diversity of perspectives contributing to innovation and growth in physics.[8]

1.3 Defining purposeful physics enrichment

Purposeful physics enrichment refers to activities beyond the formal curriculum that intentionally support young people's engagement, understanding and aspirations in physics. Drawing on science capital frameworks, this definition recognises that participation depends on access to knowledge, experiences, networks and identities, not solely interest or attainment. Sector literature identifies common characteristics of effective provision: hands-on activity, career relevance, community partnerships, and sustained rather than one-off engagement.[8,9,10] This review defines purposeful enrichment as provision that broadens access, supports sustained engagement and contributes to longer-term participation in physics. In this context, purposeful enrichment encourages and promotes positive attitudes towards physics and provides support for careers and future pathways from physics.

1.4 Policy and practice context

UK policy increasingly positions enrichment as a mechanism to address skills shortages and improve inclusion, though targeting alone does not guarantee equity.[11] Schools face ongoing challenges including shortages of specialist physics teachers and uneven external support.[12] Regional studies emphasise earlier intervention, stronger co-ordination and strategic data use.[13] This review addresses these challenges by identifying characteristics of purposeful physics enrichment that support more equitable access and participation across the UK.

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2. Methodology

2.1 Search strategy

This review adopted a systematic scoping approach with narrative synthesis to map the available evidence on physics-related enrichment and to identify key themes across diverse study designs. To maximise coverage and minimise the risk of overlooking relevant material, three complementary search strategies were employed. First, structured searches were carried out in the British Education Index (BEI), Education Resources Information Centre (ERIC) and Education Abstracts (EA) via Scopus, using four groups of terms:

1. Subject terms, e.g., physics OR physical science*
2. Enrichment terms, e.g., enrich* OR outreach OR masterclass* OR summer school* OR taster OR after school OR extra-curricular OR club OR extension OR (gifted AND talented)
3. Terms indicating impact and evaluation, e.g., evaluate* OR effect* OR impact OR outcome* OR attitude* OR engage* OR achievement OR participate*
4. Geographical restrictions, e.g., England OR United Kingdom OR UK OR Great Britain

Second, grey literature, defined here as reports, evaluations and other documents produced outside traditional academic publishing, typically by organisations, charities or government bodies, was identified through targeted searches of organisations delivering physics, science and wider STEM enrichment for school-aged students. Where evaluation reports were not publicly available, many organisations were contacted to confirm whether such materials existed. In line with ethical and data protection considerations, only reports in the public domain were included. Third, reference-list and citation searching was undertaken to identify additional studies and further reduce the likelihood of omission.

Together, these strategies generated 121 studies (Figure 1), which were subsequently screened for relevance and inclusion.

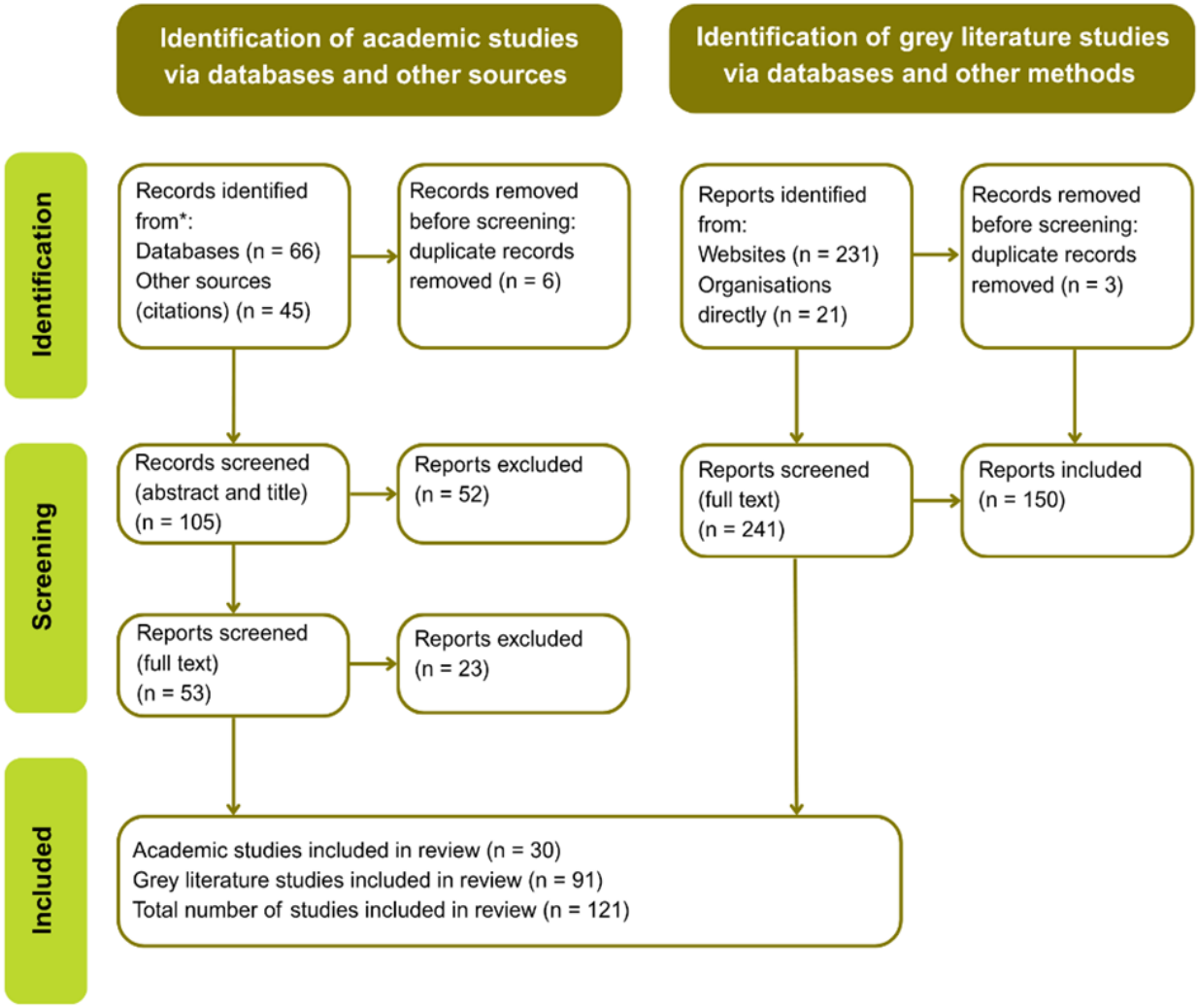

Figure 1: Detailing the phases of the search strategy and the number of studies identified, screened and included in the final review.[1]

2.2 Limitations

While a systematic scoping approach was used, we acknowledge that some relevant evidence may not have been captured, particularly activities that are not documented in publicly available reports or that are described using alternative terminology. The evidence base is also shaped by what is reported in the public domain. Some evaluations, especially within the grey literature, may be influenced by reporting bias linked to funding, accountability, or advocacy contexts, with positive or short-term outcomes more likely to be documented. In addition, although a science capital lens offers a valuable framework for interpreting enrichment activity, it has recognised limitations as an evaluative tool. As noted, science capital is not easily conceptualised as a linear or directly measurable outcome, and reliance on aggregate measures risks overlooking more nuanced or contextual forms of change.[2] Findings should therefore be interpreted cautiously and in conjunction with broader qualitative and process-based evidence.

2.3 Eligibility criteria

The following inclusion criteria were applied to studies identified during the search phase.

Inclusion criteria

Studies were required to:

- Focus on students studying in the UK.
- At secondary level, concern physics-related subjects (e.g., physics, engineering, electronics, physical sciences or geophysics). Science or STEM clubs were also included where relevant.
- At primary level, concern science-related subjects (e.g., science, computing or engineering).
- Involve an enrichment activity, defined as provision beyond normal curriculum delivery.
- Have been published since 2010, reflecting the contemporary policy and practice context of STEM enrichment.
- Contain an assessment of student outcomes (e.g., attitudes and/or progression) that could be linked to one or more of the eight dimensions of science capital.
- Be publicly available, to ensure transparency and enable verification of findings.

Exclusion criteria

Studies were excluded if they did not meet the inclusion criteria above. Eligibility criteria were applied during abstract screening (or executive summary/ introduction for grey literature). All studies were initially screened by one reviewer, with 10% double-screened by both reviewers alongside any borderline cases where eligibility was unclear. The same approach was applied at full-text screening. Numbers of studies excluded at each stage are presented in Figure 1.

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3. Conceptual and theoretical frameworks

This review is guided by a science capital framework, alongside evidence on socio-economic disadvantage and participation in physics. Together, these perspectives provide an analytical lens for examining how enrichment activities may support engagement, identity and progression, particularly for under-served groups. Science capital was selected as the primary theoretical frame because it explicitly links engagement with science to social and cultural resources, making it well-suited to examining how enrichment activities may address inequalities in physics participation.

3.1 Science capital

As outlined in Section 1, science capital describes how access to scientific knowledge, experiences, relationships and dispositions shapes young people's participation in STEM.[1,2] Developed through the longitudinal ASPIRES programme, the framework shows that students with higher science capital are significantly more likely to see themselves as 'science people' and to continue studying science beyond age 16.

Science capital is commonly operationalised through eight interrelated dimensions, which can be grouped into four broad domains:

- **What you know:** scientific knowledge and literacy
- **How you think:** attitudes, confidence, values and identity in relation to science
- **What you do:** participation in science-related activities inside and outside school
- **Who you know:** social connections to people who use or value science

These four domains encompass: understanding of science and its transferability, engagement with science media, out-of-school learning, family science resources, personal connections to people in science and everyday talk about science. Collectively, they form an individual's science capital profile: the richer this profile, the greater the likelihood of sustained engagement with science. Evidence was synthesised in terms of how different forms of provision supported one or more of these domains, enabling comparison across diverse enrichment models and outcome measures.

3.2 Socio-economic disadvantage and participation

Science capital is closely linked to social background. Longitudinal ASPIRES research shows that gender, socio-economic background and ethnicity shape access to science-related resources and experiences, with students from lower-income families typically having lower science capital.[1,2] Socio-economic disadvantage is associated with lower attainment in science at GCSE,[3] and students in the highest quintile are nearly three times more likely to take A-level physics than those in the lowest quintile, demonstrating

a strong socio-economic gradient in progression.[4] Importantly, science capital is not fixed. ASPIRES evidence shows that young people's perceptions of relevance and aspirations change over time in response to experience and social context.[1,2]

This review examines whether similar patterns are evident in enrichment beyond the formal curriculum. Specifically, it explores how physics enrichment contributes to building science capital across its key domains, and the extent to which this supports longer-term engagement and progression for students from under-represented backgrounds.

3.3 Enrichment type definitions

The literature review led to the identification of 11 distinct enrichment types, each defined below. While these categories are presented separately, some activities may span more than one type – for example, a residential programme may incorporate workshops, role model engagement and project work. For the purposes of this review, each study was coded against a primary enrichment type based on its principal reported activity, while acknowledging that in practice these boundaries are often fluid. In cases where an activity incorporated three or more enrichment types and could not be meaningfully disaggregated, it was classified as 'multiple engagement'; which is discussed further in Section 4.12.

- **Careers-related activities** – Activities that expose students to physics-related career paths and help them understand how physics knowledge applies in professional contexts.
- **Competitions** – Structured challenges where students compete individually or in teams to solve physics problems or demonstrate practical skills.
- **Family events** – Physics activities designed for students to attend with family members and carers.
- **Mentoring** – One-to-one or small-group guidance where students receive personalised support from teachers, university students, or professionals in physics fields.
- **Multi-school events** – Large-scale showcases where students from different schools present physics projects or investigations to judges and the public.
- **Projects** – Extended investigations where students design and carry out their own physics experiments or research over weeks or months.
- **Residentials** – Immersive programmes where students stay away from home for one or more nights to participate in intensive physics activities.
- **Role models** – Sessions where students meet and interact with university students, physicists or professionals who use physics, inspiring them through personal stories and experiences (individually or in small groups).

- **STEM clubs** – Regular gatherings outside lesson time where students can explore STEM ideas through hands-on activities and discussions.
- **Visits** – Trips to universities, research facilities, science centres, or workplaces where students experience physics in action beyond the classroom.
- **Workshops** – Practical, hands-on sessions (either in school or an external location) where students actively engage with physics concepts through experiments, demonstrations, or problem-solving activities.

3.4 Analytical approach

To examine the relationship between enrichment type and science capital domains, instances of reported evidence were coded against four science capital dimensions (*What you know, Who you know, How you think,* and *What you do*) and aggregated by primary enrichment type. This combined approach enabled identification of common characteristics of purposeful physics enrichment, while recognising variation in methods, contexts and strength of evidence across studies.

Workshops constitute the largest single enrichment category within the dataset (25%) and therefore account for a substantial proportion of the total coded links. Across enrichment types, the *How you think* dimension is most frequently represented, while *Who you know* appears less commonly. These patterns reflect the distribution of coded evidence within the reviewed studies rather than inferred effect size or impact strength. The smallest enrichment categories were multi-school events and family events with only three studies for each meeting the inclusion criteria.

Studies and reports were classified using two indicators of socio-economic disadvantage. An intervention was identified as having a focus on socio-economic disadvantage where the proportion of participants eligible for free school meals or pupil premium funding exceeded the national average (25.7%). This threshold was applied to either the overall participant cohort or to clearly reported subgroups within the study. Where such data were available, classification was based on reported participant characteristics rather than inferred targeting.

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4. Findings from the literature

Note on robustness, breadth and science capital impact qualifications

Robustness

Studies considered to have greater methodological robustness included experimental (i.e., randomised controlled trials) and quasi-experimental approaches. These studies also used validated measures of student outcomes on students directly rather than relying on a proxy. Typically, studies considered less robust used a proxy (e.g., teachers' or parents' perceptions of the impact on student attitudes) and/or created a novel measure of student impact that had not been validated. Further detail on robustness is provided within each sub-section.

Rating	Key
Weak	Majority of studies reviewed in this area used less robust methodology
Moderate	The methodology was of varying robustness in studies reviewed in this area
Strong	The majority of the studies reviewed in this area used robust methodology

Breadth

The breadth rating reflects the number of studies identified for each enrichment type, as follows:

Rating	Key
Narrow	1–5 studies included within this area
Moderate	6–10 studies included within this area
Broad	11+ studies included within this area

Science capital impact

Each enrichment type is also accompanied by a summary of its impact across the four science capital domains: *What you know*, *Who you know*, *How you think* and *What you do* (see Section 3.1). A tick (✔) indicates that more than half of studies reviewed in that section report a meaningful contribution from this type of enrichment to the relevant domain. The absence of a tick does not necessarily mean the enrichment type has no impact in that area, but rather that the evidence reviewed did not report consistent or substantive findings against that domain. These indicators should therefore be read as a high-level summary of where the evidence base is currently strongest, rather than as a definitive measure of impact. Detailed evidence and discussion supporting each judgement is presented within the relevant sub-section.

4.1 Careers-related activities

Breadth of evidence	Broad
Strength of evidence	Moderate

Overall science capital impact

What you know	*Who you know*	*How you think*	*What you do*
	✔	✔	

Career-related activities most consistently helped when they combined hands-on tasks, clear information about education and career pathways, and contact with employers or relatable role models (e.g., individuals with similar backgrounds or experiences). Several evaluations examined in-school careers events combining hands-on activities with employer or role model engagement. Future First evaluated *Infinity Labs*,[1] a three-session workshop series pairing alumni role model talks with an online careers game, and found increased aspiration, particularly where volunteers shared similar backgrounds. The Engineering Development Trust combined college visits, university tasters and industry engagement in their three-day *Routes into STEM* programme, finding increased awareness of alternative pathways including apprenticeships alongside improved confidence and problem-solving skills.[2] Whalley and Cummings reported that the National Space Academy *Space to Learn Career Conferences* increased career navigation knowledge, though attitudinal and aspirational measures showed smaller or no change respectively.[3]

University-based events targeting underrepresented groups also demonstrated impact on awareness and enthusiasm. UK Electronics Skills Foundation delivered single-day events for girls aged 14-17, using hands-on electronics activities and direct encounters with professionals to inspire 80% of participants and newly motivate 56% of those not previously considering the subject.[4] The Welsh *Spark their Imagination* programme similarly combined teaching resources, teacher training and workshop career events featuring microcontroller kits alongside semiconductor researchers.[5] Stevens et al. found through qualitative evaluation that *Tomorrow's Engineers* careers materials broadened students' understanding of engineering disciplines and routes, with visual representations of female engineers helping challenge gender stereotypes, though behavioural outcomes were not measured.[6]

Sustained, curriculum-integrated interventions showed impact on career knowledge and aspirations. Emembolu et al. designed career-driven STEM activities delivered across six primary schools over two years.[7] Students used the ‘STEM Career Knowledge and Aspirations Tool’, sorting STEM-related job cards into piles of those they knew, and jobs they would like to do. The research team found this broadened students’ career

knowledge and reduced gender gaps in STEM job awareness. Bórquez-Sánchez et al. evaluated the *Children Challenging Industry* programme,[8] which linked curriculum science to local industry through classroom modules and visits, finding statistically significant increases in attitudes to science and career knowledge among over 500 primary students, with strongest effects for those with low baseline awareness. Edmonds et al. examined the *Children as Engineers* programme,[9] which embedded undergraduate engineer outreach within classroom-based design tasks, finding that many primary students expressed engineering ambitions early, though aspiration was not simply predicted by positive attitudes to single subjects.

Approaches using careers resources and games provided alternative engagement methods. Murray and Dunstan developed *Diamond: The Game*,[10] a board game immersing students in research roles across STEM careers and reported through pre-post measures that gameplay promoted consideration of career breadth and interdisciplinarity. Archer, L. et al. evaluated a six-week teacher-led pilot in a girls' school incorporating careers activities, STEM professional visits and project work, finding increased career awareness but negligible change in aspirations.[11] Glover et al. evaluated the multi-strand *STEM Cymru 2* programme,[12] with participants, particularly in the girls-only strand, reporting increased confidence and awareness of higher education and career routes. Bridle and Rajendran found that the *Let's Do Engineering* intervention improved engineering identification among five-to-six-year-olds from 44% to 75%, albeit with a sample of only 16 children (see also Bridle et al.).[13, 14]

Implications for practice: Career-focused enrichment is most effective when it combines hands-on tasks with clear information about routes into physics-related careers and direct contact with employers or relatable role models. Providers should seek to encourage and promote positive attitudes towards physics by embedding career awareness within sustained, curriculum-linked activities, rather than relying on one-off events. Supporting careers and future pathways from physics should be a central objective.

4.2 Competitions

Breadth of evidence	Narrow
Strength of evidence	Weak

Overall science capital impact

What you know	*Who you know*	*How you think*	*What you do*
✔		✔	✔

Only five studies were identified that evaluate competition-style STEM enrichment interventions. The evidence base includes large-scale survey data from the IET *Faraday*

Challenge Days, showing very high enjoyment and perceived learning, and an increase in the proportion considering an engineering career (34% pre-event to 58% post-event) (see also Lummis et al.).[1,2] The *FIRST LEGO League* evaluation reports improvements in students' understanding of engineering problem-solving and gains in problem-solving and teamwork skills, with qualitative evidence suggesting potential benefits for girls, disadvantaged students and those with SEND, and some influence on longer-term subject choices.[3] Hoshin reports on *F1 in Schools*, finding that teacher and student accounts emphasise sustained skill development and the potential for competitions to become embedded in school provision, with indicative longer-term value through references in UCAS and employment contexts.[4] The *British Physics Olympiad* (BPhO) evaluation similarly indicates qualitative accounts of increased confidence in approaching unfamiliar problems, but notes that there is already a high baseline interest/intention prior to participation.[5] Evidence for *Who you know* is comparatively limited across the competition studies, with few direct measures of changes in students' STEM networks or relationships. Across the five studies, outcomes are predominantly positive. However, evidence from the British Physics Olympiad suggests that competition-based enrichment may produce uneven effects where activities are highly demanding and participation is concentrated among already highly motivated and less socio-economically disadvantaged students (only 11.1% of participating English non-fee-paying schools in the most disadvantaged IMD quintile), highlighting an equity consideration for competition-based enrichment.[5] Similarly, the *Robotics Challenge* reports very high engagement (97% enjoyment) and strong motivation, with 89% of students wanting to do more STEM activities and 81% wanting to learn more about engineering careers. However, the cohort is already highly STEM-engaged (73% high prior engagement), and the programme appears to have primarily reinforced existing interest for many students rather than broaden participation. There are also inequalities in engagement, with teachers noting challenges in reaching girls, and those with low prior exposure to STEM. While the programme improved careers awareness, gaps remain in students' understanding of pathways into engineering, suggesting a need for stronger careers support and outreach to less-engaged groups.[6]

Implications for practice: Competition-based enrichment can build confidence in physics ability but raises equity concerns, as participation tends to be concentrated among already motivated and less disadvantaged students. Providers should consider complementing competitions with broader access strategies and monitoring who participates.

4.3 Family learning events

Breadth of evidence	Narrow
Strength of evidence	Weak

Overall science capital impact

What you know	*Who you know*	*How you think*	*What you do*
✔		✔	✔

Evaluations of family learning events generally focus on a smaller cohort of attendees. The *Me, You and Science Too* project was a school-based STEM and literacy programme that brought families and younger students together through regular story-reading sessions and simple science activities.[1] The evaluation found it increased STEM literacy in the home, enjoyment of shared reading, and strengthening home-school relationships, while also helping schools better engage families. However, the impact on behaviour was mixed: while families used the books regularly and broadened the types of reading they did, STEM activities were less frequently repeated at home, suggesting that deeper or more sustained support is needed to embed ongoing family STEM practices.[1]

Many family learning events also include a workshop element, meaning students have repeated opportunities to engage in scientific activities. NUSTEM's summary report on *STEM Communities* similarly demonstrated positive outcomes through sequential school and museum interventions,[2] with 78% of students feeling able to ask questions and 39% of families returning multiple times. NUSTEM's smaller-scale evaluation of *Engineering for Families*,[3] a six-week programme across six Northumberland primary schools, found qualitative evidence that family co-participation raised STEM career aspiration amongst participating children and their families. The evaluations demonstrate that sustained, relationship- and family-focused programmes produced the most robust, longer-term impact on students' science capital.

Implications for practice: Family learning events are most effective when they adopt sustained partnership approaches and go beyond one-off showcases. Designing activities that families can continue at home and that build belonging and relevance supports longer-term development of science capital.

4.4 Mentoring

Breadth of evidence	Medium
Strength of evidence	Moderate

Overall science capital impact

What you know	*Who you know*	*How you think*	*What you do*
✔	✔	✔	✔

Mentoring programmes can demonstrate positive impacts on all aspects of science capital, particularly as they enable sustained engagement with relatable role models. The *Physics Mentoring Project* found that weekly small-group sessions across Welsh secondary schools enhanced confidence, engagement, and post-16 physics intentions among students in years 9-11, with outcomes stronger than comparison groups.[1-4] Teachers noted the relational, discussion-led approach effectively engaged learners resistant to traditional instruction. Cramman et al. and Cottle et al. evaluated the *Levelling Up* project, a university-based Year 12 physics programme providing online tutorials and near-peer mentoring, reporting increased confidence in physics problem-solving, clearer university pathway awareness, and strengthened sense of belonging.[5,6] However, Cramman and colleagues noted variable attendance limited impact consistency.

Collectively, these two studies suggest that structured mentoring can support multiple science capital dimensions through increased confidence, strengthened STEM identity, and career awareness, though longer-term progression tracking remains limited.

Implications for practice: Structured mentoring can support all four science capital dimensions, particularly through sustained engagement with relatable role models. Programmes should ensure consistent attendance and provide relational, discussion-led approaches that encourage and promote positive attitudes towards physics.

4.5 Multi-school events

Breadth of evidence	Narrow
Strength of evidence	Moderate

Overall science capital impact

What you know	*Who you know*	*How you think*	*What you do*
		✔	

Multi-school events have the potential to inspire young people and build science knowledge, although evaluators note caveats regarding the efficacy of different approaches. Canovan (2020) interviewed organisers of five UK science festivals and conducted an in-depth two-year case study at one festival, finding that organisers and teachers prioritised affective outcomes.[1] Almost all students reported increased inspiration, just under half reported factual gains, but students rarely reported careers learning. EngineeringUK's evaluation of *The Big Bang Fair* surveyed over 2000 students and documented strong short-term increases in STEM job knowledge, inspiration to consider STEM careers and intention to do more STEM activities.[2] Straw et al. evaluated the *Bloodhound Education Programme* through interviews and observations with teachers, students, and project ambassadors, finding that young people gained enthusiasm for engineering and increased STEM knowledge, whilst some developed wider skills in teamwork and problem-solving.[3] However, careers learning, a goal for organisers and some teachers, rarely translated into evaluating student outcomes across these studies. These studies demonstrate that large-scale events can spark interest and build knowledge, though clearer communication about careers goals could strengthen this impact. Additionally, understanding of the impact of science fairs would benefit from longer-term follow-up to gauge the enduring impact on students' science capital.

Implications for practice: Large-scale events can spark interest and build knowledge but rarely translate into sustained careers learning. Organisers should build in explicit career messaging and follow-up activities to strengthen impact on pathways from physics.

4.6 Projects

Breadth of evidence	Broad
Strength of evidence	Moderate

Overall science capital impact

What you know	*Who you know*	*How you think*	*What you do*
		✔	✔

Project-based enrichment that gives students sustained ownership of authentic investigations strengthens confidence, skills and career clarity, provided programmes allow enough time and support, for example, through mentoring. There were mixed findings regarding *CREST Silver*, where Husain et al.'s RCT found no short-term attainment effect, noting low project completion, time pressures and curriculum conflicts.[1] By contrast, Stock Jones et al. found longer-term academic benefits and increased STEM A-level uptake, especially for disadvantaged students, as noted below.[2] Thomas et al. found that *Mission X*'s flexible astronaut-themed activities increased primary students' science enjoyment, confidence, and space knowledge, with strong accessibility for students with SEND.[3] Extended, hands-on projects that partner students with researchers or industry showed clear gains. Archer, M. et al., evaluated a six-month programme involving 153 students across 37 London schools, finding increased self-reported topic knowledge, participation in extended science activities, and awareness of physics roles among participants.[4] Three years post-programme, almost all of the small follow-up cohort (13/14) were studying STEM degrees, though this represents only a fraction of original participants. Student-led approaches show promise: the *Orbyts* programme used real data and STEM Fellows to increase participants' research skills, self-efficacy and networks,[5] the *Young STEM Leader* Programme increased STEM career awareness and increased development of essential skills,[6] while the *Wales Education Engineering Scheme* increased STEM aspirations and essential skills.[7] The *Hareclive in Space* project built students' confidence and agency through co-created inquiry.[8] The most successful projects were longer-term with strong mentor or industry links, clear completion routes and scaffolds to provide authentic research experiences for all students.

Implications for practice: Project-based enrichment is most effective when it provides sustained ownership of authentic investigations with strong mentor or industry links. Providers should ensure clear completion routes and appropriate scaffolding, particularly for disadvantaged learners, to support careers and future pathways from physics.

4.7 Residentials

Breadth of evidence	Narrow
Strength of evidence	Moderate

Overall science capital impact

What you know	*Who you know*	*How you think*	*What you do*
		✔	✔

Studies suggest that residential physics and engineering programmes can demonstrate positive impacts on students' university aspirations and subject engagement. The Engineering Development Trust found that 269 students completing the *Insight into University* programme showed increased interest in pursuing a STEM pathway.[1] The University of Oxford's *Uncover Engineering* programme saw virtually all its 72 participants indicate an increased likelihood to apply to university to study engineering.[2] Hoshin's evaluation of *Headstart Cymru*,[3] involving 267 students, similarly found participants more likely to consider university and study engineering. These programmes particularly strengthen the 'what you do' science capital domain through sustained, immersive experiences. Durk et al. demonstrated that intensive learning experiences also impact 'what you know' and 'how you think' domains; their quasi-experimental study of around 200 students at an *Isaac Physics* bootcamp found significant increases in both physics ability and self-efficacy, with socio-economic gaps in ability eliminated for covered material.[4] Space Camps were multi-day immersive experiences for students aged 10–18 years, involving hands-on STEM activities and group projects. The evaluation found they increased student enjoyment of science, as well as understanding the relevance of science and awareness of career pathways. The space camps also supported the development of transferable skills such as teamwork and communication. However, their impact on changing long-term aspirations was more limited, with only modest increases in interest in STEM careers, partly because many participants already had a pre-existing interest in the subject.[5] Across these evaluations, multi-day residential experiences combining hands-on activities, university exposure, and real-world problem-solving emerge as particularly effective in building engagement and informed decision-making among secondary students. However, it is important to note that residential programmes engage a relatively small number of often self-selecting students.

Implications for practice: Residential programmes combine intensive, immersive experiences that effectively build engagement and confidence. However, their reach is inherently limited. Providers should consider targeted recruitment strategies to ensure disadvantaged students can access these opportunities.

4.8 Role models

Breadth of evidence	Broad
Strength of evidence	Moderate

Overall science capital impact

What you know	*Who you know*	*How you think*	*What you do*
	✔	✔	✔

Schools and outreach programmes increased students' engagement, confidence and STEM career interest when they combined hands-on activities, real-world relevance and direct engagement with STEM role models. Sadler et al. found through surveys of 363 primary students that a role model-based science show increased STEM career aspirations,[1] with statistically significant gains overall and larger effects in girls. The intervention also reduced negative stereotypes about scientists being 'nerdy' or 'crazy'. Shimwell et al.'s evaluation of a five-week *Scientist of the Week* intervention also showed a reduction in primary-aged students' stereotypical views of scientists, which persisted in the follow-up a year later.[2] STEM Learning evaluated 41 *Targeted Interventions* involving over 74,000 young people and found statistically significant improvements in STEM career awareness, role model engagement, and subject enjoyment, with secondary students showing a 16% increase in perceiving STEM as important.[3] SQW documented the *STEM Ambassador* programme's extensive reach through mixed methods, delivering 181,000 activities to an estimated 15-26 million young people, though quantitative impact evidence remained limited.[4] Wilkinson and Jackson identified improved engagement and confidence through the *STEM Ambassador* programme across seven qualitative case studies, with notable benefits reported for underrepresented groups.[5] Corcoran and McNicol similarly found that Space Ambassadors in the *Tim Peake Primary Project* increased motivation and aspirations, particularly among girls and students with SEND.[6] Gartland's ethnographic study at two universities observed that subject-specific outreach activities could support under-represented students' interest.[7] Collectively, these studies suggest that interventions featuring hands-on activities, real-world relevance, and direct or indirect engagement with relatable STEM professionals produce measurable gains in engagement, aspirations, and self-efficacy.

Evaluations of online contact with role models extend these findings, highlighting the additional opportunities digital formats provide for accessing role models and enabling participation at scale. As part of the STFC evaluation, *I'm a Scientist* & *I'm an Engineer* reported that 91% of 9,516 students engaged actively with the I'm a Scientist text-based platform, with teachers noting increased motivation and confidence.[8] I'm a Scientist (2019) similarly found that the informal and anonymous nature of online engagement lowered perceived barriers to participation, encouraging students to ask personally meaningful questions.[9] Plaister and Hamer identified a 15% increase in positive descriptors of physicists following participation,[10] alongside improved awareness of physics-related jobs among girls, while the CERN Zone evaluation reported heightened curiosity and improved understanding of research careers following virtual chats.[11] Comparable outcomes were observed in interactions during online assemblies where *STEMAZING* trained 219 women in STEM to deliver virtual sessions to 12,574 primary students, with 77% of teachers reporting improved STEM awareness in of children and 75% of teachers reported reduced gender stereotyping amongst their students.[12]

Implications for practice: Role model interventions are most effective when they feature relatable professionals and are embedded within hands-on activities. Both in-person and online formats can encourage and promote positive attitudes towards physics, particularly where they lower barriers to participation for underrepresented groups.

4.9 STEM clubs

Breadth of evidence	Broad
Strength of evidence	Moderate

Overall science capital impact

What you know	*Who you know*	*How you think*	*What you do*
		✔	✔

Multiple evaluations indicate that extracurricular STEM clubs can be associated with improvements in student engagement, confidence and practical skills, though evidence of attainment gains is more mixed and appears sensitive to implementation quality and duration. STEM Learning's evaluation of *STEM Clubs*,[1] based primarily on teacher and student survey responses, reports perceived increases in students' enjoyment of STEM subjects, confidence in practical work and engagement with learning, with teachers highlighting hands-on activities and informal learning environments as key contributors to these outcomes. Separately, NFER's evaluation of *STEMNET* programmes found that teachers commonly reported improvements in students' engagement, teamwork and practical skills following participation in STEM clubs and related enrichment, while also noting that sustained involvement over longer periods was associated with stronger perceived benefits.[2,3]

Straw et al. conducted a randomised controlled trial with over 300 Year 5 students participating in *Code Club* and found no statistically significant impact on a standardised computational thinking test.[4] However, the study did identify improvements in students' coding skills and teacher-reported increases in confidence and engagement. Siddiqui et al. similarly reported gains in coding competence and self-confidence in a quasi-experimental study involving over 400 students, though effects varied across settings and depended on consistency of delivery.[5] The Behavioural Insights Team's analysis of *Code Club* similarly found that while the programme provides an accessible, creative environment, girls' participation remained lower than boys', suggesting that voluntary club models may reinforce rather than reduce gender disparities without broader structural approaches.[6] Maglicic et al. evaluated *Apps for Good*, a 12-hour extracurricular coding course for Year 8 girls, finding a small but statistically significant improvement in attitudes towards computing but no change in intention to take GCSE Computer Science.[7]

Smaller-scale studies reinforce these patterns: Magaji et al. observed improvements in Progress 8 scores among 17 secondary students attending science clubs, while Hobbs et al. reported positive engagement and learning outcomes for 29 students with SEND using Minecraft-based science activities.[8,9] Clark et al. evaluated *Creativity Clubs*, a year-long weekly STEM club for children aged 4–7, finding that participants developed confidence, communication skills and a stronger sense of belonging, with observations highlighting the importance of high staff-to-child ratios and consistent adult support for younger age groups.[10]

Evidence from data-enabled and online STEM club models further highlights the value of authentic scientific practice. Hope-Stone Research, evaluating the *National Schools Observatory*, found that access to real telescope data supported students' inquiry skills and confidence, with 61% of secondary students reporting increased interest in STEM following participation.[11] Teachers also described improvements in students' independence and willingness to ask scientific questions, suggesting that engagement with genuine research tools can strengthen both participation and scientific reasoning. Across studies, implementation conditions emerge as critical. Siddiqui et al. report that sustainability was constrained by volunteer availability and variability in delivery models,[5] while Straw et al. emphasise that inconsistent attendance reduced potential impact.[13] Clapham also identifies tensions between teachers' valuing of informal STEM learning and exam-driven accountability pressures, which can limit uptake and continuity.[3]

Implications for practice: STEM clubs can improve engagement and confidence when delivered consistently, but sustainability depends on volunteer availability and school resourcing. Clubs incorporating authentic scientific practice and real data show particular promise for building science capital, though voluntary participation models may not address gender disparities without complementary recruitment strategies.

4.10 Visits and trips

Breadth of evidence	Medium
Strength of evidence	Moderate

Overall science capital impact

What you know	*Who you know*	*How you think*	*What you do*
✔		✔	

Evaluations of STEM-focused trips and visits reveal several effective features that could develop students' science capital. Jesionkowska et al. (2020) evaluated a two-day university-based extracurricular workshop where 15 students built augmented reality applications.[1] They found that project-based maker activities enhanced students'

perceived coding and problem-solving skills alongside their motivation, though the small-scale pilot relied on self-reports. Glasgow Science Centre's *Learning Lab* similarly combined multi-week preparation, a science-centre visit and interaction with industry role models, with teacher surveys indicating increased ability to connect science to everyday life.[2] Short-duration visits also showed strong impacts: Destination Space delivered one-hour space-science workshops and live shows with hands-on activities, recording high enjoyment and increased career interest,[3] with subsequent phases demonstrating enhanced understanding of real-world relevance.[4,5] Scott and Boyd demonstrated through fieldwork that hands-on, inquiry-based experiences improved both science knowledge and literacy.[6,7] Archer, L. et al. found through interviews with 20 families that pre-existing cultural capital significantly shaped whether visits were experienced as disorientating, merely fun, or meaningfully educational.[8] Families with greater science knowledge and familiarity with museum norms were better able to leverage learning opportunities, while those lacking scientific language skills or whose first language was not English experienced barriers to engagement. This suggests that while trips can effectively build science knowledge, their accessibility and impact may vary considerably depending on participants' starting points. Collectively, visits combining curriculum alignment, hands-on interaction, real-world contexts and expert contact appear most effective.

Implications for practice: Visits are most effective when they are curriculum-aligned, include preparation activities beforehand, and engage families. Providers should be aware that pre-existing cultural capital significantly shapes visit experiences, and plan accordingly to ensure accessibility for students with lower science capital.

4.11 Workshops

Breadth of evidence	Broad
Strength of evidence	Weak

Overall science capital impact

What you know	*Who you know*	*How you think*	*What you do*
✔		✔	✔

Workshops delivered the most reliable short-term gains when designers paired hands-on investigation with clear curriculum links, explicit tasks and authentic role models, according to evaluations. Davenport and Morton ran two in-school sessions pairing a solar physicist with a visual artist so students built annotated models of the Sun; evaluators observed clearer application of science concepts in students' diagrams and a small rise in interest in science careers.[1] Weldon and Hou ran a six-week *DIY Orchestra* project that wove music with physics (vibration, resonance), and facilitator reflections plus student feedback showed increased curiosity, confidence, collaboration and

problem-solving.[2] Canovan et al. similarly integrated physics concepts through dance videos and classroom investigations in *Into Our Skies*, with teachers reporting increased student curiosity and participation compared to typical lessons.[3]

Other workshops incorporating role models showed sustained impact on the ‘What you know’, ‘Who you know’ and ‘How you think’ science capital domains, such as Thomas’s report on the *Zooniverse in Schools* project, which involved direct researcher interaction.[4] However, Kerr found that while student-professional discussions about the space sector generated rich engagement, professional contact alone did not overcome students' ethical concerns about sector values.[5]

Sequenced or multi-session models strengthened outcomes: SEPnet's *Connect Physics* used three linked one-hour workshops and researcher visits to situate physics in everyday contexts; Hope-Stone Research and Keenan and Thorley found modest change on large-scale science-capital indicators but consistent teacher and student reports that physics felt more approachable and that short-term interest rose.[6,7] Thorley's evaluation of *SunSpaceArt* documented widespread teacher confidence gains, sustained student recall, and particular benefits for learners with lower prior science capital when creative tasks paired scientists with classroom activities.[8] Boyle reported similar positive outcomes from a gravitational-waves teaching module combined with year-long extra-curricular project activities, though evaluation was limited by small samples.[9]

Single-session, practical workshops delivered high engagement and perceived learning where tasks foregrounded inquiry. CFE Research's *Energy Quest* found strong ratings for hands-on renewable energy challenges across 129 schools (including over 11,000 students), with 87% reporting better understanding of engineering roles and 45% indicating increased career interest.[10] The *Binding Blocks* LEGO activity improved conceptual clarity and confidence about nuclear topics, with especially strong responses for some female students.[11] Engineering Education Scheme *Wales Semiconductor Project* used electronic kits across four schools, with staff noting strong engagement in circuit-building activities.[12] Muller et al. reported increases in positive science attitudes following *Blue Marble* one-day workshops linking space industry and Earth observation to curriculum topics.[13] Bartlett examined Explorer Dome's *Our Space Our Future*, combining planetarium shows, researcher talks and hands-on workshops across 7 schools, with pre-post surveys of 1,048 students showing statistically significant shifts in enjoyment of space learning.[14] Another evaluation of science shows, conducted by Sadler, demonstrated remarkable long-term retention, with 25% of demonstrations from a science show recalled unprompted 2.5 years later.[15] Padwick et al. tested an educational board game where children aged 7-11 played collaboratively to limit global temperature rise below 1.5°C through climate action decisions. Ethnographic analysis

found that the game helped students to grasp key climate concepts and the urgency of collective action.[16]

Jeavans and Jenkins evaluated *Shattering Stereotypes*, a year-long programme including gender stereotyping workshops and communication challenges.[17] While some positive shifts occurred (e.g., 'Physics is for me' increased for boys), the evaluation revealed complexity: perceived difficulty increased significantly overall (33.3% to 54.4%), particularly for girls, highlighting that stereotype interventions alone may have mixed effects. Several programmes incorporated inclusive designs, such as 3D-printed tactile models for visually impaired learners, VR/sensory adaptations, and high staff ratios in SEND settings. Evaluations found that accessible, multimodal workshops let more students participate independently and increased participants' curiosity.[18,19] Other activities were talk-focused, for example, McLaughlin et al.'s series of public engagement seminars involving AS-level physics students (aged 16-17) at Further Education colleges. Feedback indicated a large proportion of the 50 students surveyed agreed that the talks had had a positive impact on their self-reported interest in and engagement towards science.[20]

Across studies, common limitations recur: many evaluations rely on self-report, short pre/post windows or small non-matched samples. Methodological considerations aside, evaluations show that successful workshops link to the curriculum, use authentic role models, are carefully sequenced, utilise inquiry tasks, and incorporate accessibility into the design.

Implications for practice: Workshops deliver the most reliable short-term gains when they pair hands-on investigation with clear curriculum links and authentic role models. Sequenced or multi-session models strengthen outcomes. Inclusive design features such as multimodal delivery and high staff ratios can support wider participation.

4.12 Multiple engagement and sustained provision in physics enrichment

Although this review set out to examine discrete enrichment types, much of the literature instead describes provision that combines multiple approaches delivered in parallel, for example, workshops integrated with careers learning and role model engagement. Indeed, many of the strongest examples bring together curriculum-linked activities, careers engagement, role models and family involvement within sustained partnerships that adapt to different school contexts and student needs, as discussed by Archer, M., et al.[1] Prominent UK examples include programmes led by the Institute of Physics (IOP) (notably *Opportunities from Physics* and *Improving Gender Balance*), the Royal Academy of Engineering (*London Engineering Project* and *Welsh Valleys*

Engineering Project), and long-term collaborative partnerships developed by NUSTEM.[2-8]

The IOP's *Opportunities from Physics* programme provides a clear illustration of this integrated model.[2] Delivered over two years in a London secondary school with 33% of students eligible for free school meals, the programme combined classroom activities, demonstrations, lectures, workplace visits and a physics careers event for parents. Evaluation highlighted the importance of sustained relationships with the school, close alignment with teacher priorities, and responsiveness to students' interests (including medicine, space and digital technologies). Rather than following a fixed package, provision evolved in response to classroom context and emerging learner needs.

4.13 Cumulative impact over time

Crucially, student engagement and aspirations could not be attributed to any single component. Instead, impact was associated with the cumulative effect of multiple, aligned interventions delivered over time, reinforcing the importance of coherence and continuity in enrichment design.[2]

Comparable approaches underpin Royal Academy of Engineering initiatives such as the *London Engineering Project* and *Welsh Valleys Engineering Project*, which combine workshops, clubs, competitions, mentoring and employer engagement over several years. These programmes are characterised by sustained collaboration between schools, universities and industry partners, with delivery tailored to local socio-economic contexts and institutional capacity. Similarly, NUSTEM's long-running partnerships integrate repeated workshops, whole-school projects, family learning and teacher development. Evaluation evidence indicates stronger outcomes where engagement is maintained across multiple years rather than provided as short-term input, for example, improved career awareness and more positive perceptions of scientists among students experiencing two or more years of involvement.[7,8]

4.14 Focus on socio-economic disadvantage

Absence of evidence

Most studies (91%) examined did not disaggregate by student disadvantage based on the criteria. We recognise that it can be challenging, as it is not always appropriate to collect this information. Even when studies mentioned a focus on disadvantaged groups, there were occasions where these did not meet our criteria: a greater than national average proportion of students in receipt of pupil premium or free school meals funding, either within the whole cohort evaluated, or reported separately. Those that did meet our criteria are reported by enrichment activity below. Findings for impact on the science capital of socio-economically disadvantaged students are tentative, given the relatively low numbers of studies meeting the criteria.

Careers

EDT's *Routes into STEM* reached high proportions of learners from disadvantaged areas and students receiving free school meals and reported increased awareness of pathways and skills confidence among these groups, suggesting co-ordinated, multi-day, employer-linked experiences can improve the 'who you know', 'what you do' and 'how you think' domains of science capital for socio-economically disadvantaged students.[1]

Family events

The *Explore Your Universe 3* programme evaluated by Dillon and Moncada Arce (2018) assessed socio-economic disadvantage using schools' postcodes.[2] The programme had a slightly more positive impact on the attitudes of students from schools in areas of higher deprivation than those in more affluent areas. Further evidence is needed, however, on the impact of family events on students in receipt of pupil premium funding specifically.

Multi-school events

EngineeringUK's evaluation of *The Big Bang Fair* and Canovan's qualitative study of UK science festivals both included proportions of socio-economically disadvantaged students that exceeded the national average.[3,4] Canovan warned that festivals may under-represent disadvantaged students and showed limited careers learning. In addition, gains in science capital may be relatively short term, and evaluations show little evidence on sustained gap-narrowing.

Projects

Stock Jones et al. found *CREST Silver* participants eligible for free school meals achieved two-thirds of a GCSE grade higher in science compared to matched controls, a stronger effect than for non-FSM students (half a GCSE grade increase).[5]

Residentials

Durk et al. found that the *Isaac Physics* bootcamp eliminated ability gaps by socio-economic status for material covered in the intervention, demonstrating a particular impact on the 'what you know' science capital domain for disadvantaged students.[6] The intervention also increased self-efficacy across all participants, though specific gains for socio-economically disadvantaged students on this measure were not separately reported.

Role models

STEMAZING (2024) highlights that role models play an important role in shaping young people's aspirations and sense of belonging in STEM by helping them see these careers as achievable and relevant to them. Notably, the programme reached a diverse cohort, with 32.4% of participating students eligible for free school meals.[7]

Workshops

Two Institute of Physics *Planet Possibility* workshops demonstrated some effectiveness with socio-economically disadvantaged learners. The Lightyear Foundation delivered bubble-wand prediction experiments in a special school with high proportions of students with SEND, EAL and socio-economic disadvantage, with teachers reporting that typically struggling students showed heightened focus and felt successful in science, strengthening 'what you do' and 'how you think' science capital domains.[8] The Blair Project brought their STEM Truck with electric kart engineering activities to a Greater Manchester Year 9 cohort, where hard-to-engage girls successfully completed engineering challenges and several students continued science exploration at home.[9] Emembolu et al. recruited students eligible for free school meals for a 90-minute workshop about environmental planning careers, focused on coastal risk-mapping, where children analysed historical and current maps to understand landscape changes over time.[10] The programme had a positive impact on students' scientific literacy and conceptual knowledge but the impact on scientific career aspirations was mixed: many children reported they would not want to be environmental planners or were unsure after the workshop.

5. Conclusions

5.1 Summary of what works for physics enrichment

This review identifies several characteristics of effective physics enrichment. The strongest impacts emerge from sustained, multi-component interventions that combine curriculum-aligned activities, hands-on investigation, authentic role model engagement, and career awareness over extended periods. Mentoring programmes demonstrate moderate-strength evidence of positive impacts across all four science capital domains, particularly when featuring relatable role models and sustained contact. Research into project-based enrichment shows similar breadth, while residentials and targeted careers interventions combining hands-on tasks with employer contact show promise in strengthening engagement, confidence, and pathway awareness.

Evidence for socio-economically disadvantaged students reveals both encouraging findings and significant gaps. CREST Silver participants eligible for free school meals achieved two-thirds of a GCSE grade higher in science compared to matched controls – a stronger effect than for students who do not have free school meals. The Isaac Physics bootcamp reduced knowledge gaps for students from the most socio-economically disadvantaged backgrounds, demonstrating impact on the 'what you know' science capital domain. However, competition-based enrichment raises equity concerns, with participation concentrated among already motivated and less disadvantaged students. Across intervention types, evidence on sustained gap-narrowing remains limited, and many evaluations do not disaggregate outcomes by socio-economic background.

5.2 Evidence gaps and areas for further research

Methodological limitations constrain confidence in findings across enrichment types. Many evaluations rely on self-report measures, short pre-post windows, or small non-matched samples. Long-term follow-up tracking remains rare beyond isolated examples, limiting understanding of sustained impact on subject choices, career pathways, and gap-narrowing. The 'who you know' science capital domain receives comparatively limited direct measurement, with few studies examining changes in students' STEM networks or relationships. Workshop interventions show broad breadth but weak strength of evidence, highlighting the need for more rigorous evaluation designs. Understanding differential impact by gender, ethnicity, SEND status, and socio-economic background requires more systematic disaggregation of outcomes across all intervention types.

5.3 Opportunities to lead purposeful enrichment practice

The evidence base reveals clear opportunities for improving physics enrichment design and delivery. Demonstrating cumulative impact is critical – student engagement and aspirations cannot be attributed to single components but rather to multiple, aligned interventions delivered through sustained collaborative partnerships. Programmes combining workshops, clubs, competitions, mentoring, and employer engagement over several years show stronger outcomes where engagement is maintained across multiple touchpoints. Implementation quality matters substantially: sustained involvement, consistent attendance, volunteer availability, and alignment with teacher priorities all influence effectiveness. The most successful approaches embed enrichment within curriculum contexts, provide authentic research experiences through industry or university partnerships, feature relatable role models from diverse backgrounds, and include clear completion routes with appropriate scaffolding for all students.

5.4 Drawing up recommendations

Drawing together the evidence by activity type and the cross-cutting characteristics of effective enrichment, this review puts forward a set of recommendations for funders, schools and teachers, and policy makers and the wider sector (see Recommendations at the start of this document). These recommendations are evidence-informed in two senses. They reflect the strength, breadth and science capital impact of the evidence relating to each individual enrichment type, as set out in Section 4. They also reflect the common features that distinguish purposeful enrichment across types – sustained engagement, multi-component design, collaborative partnerships, relatable role models, curriculum alignment and attention to equity of access. Taken together, the recommendations are intended to support more purposeful, equitable and effective physics enrichment across the UK, while recognising the evidence gaps that should shape future research and evaluation.

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