INSPIRING MINDS

NEON Innovation Series Evaluation Report

National Collaborative Outreach Programme

KMPF KENT & MEDWAY PROGRESSION FEDERATION

Canterbury Christ Church University

INSPIRING MINDS

The Inspiring Minds sessions empower students with new ways to think about themselves, their school subjects and what they can do next. In order to do that they need commit to coming to each session with an open mind and willingness to ask big questions about their world.

The activities build their ability to think across their subjects and beyond, to ask good questions and to make good use of what is already known to achieve their CREST award.

This is their chance to show the world what they are made of, what has inspired them and to inspire us with their solutions!

Epistemic Insight

Canterbury Christ Church University

Inspiring Minds through Informal Science Learning: NEON Innovation Series evaluation report.

An evaluation of the impact when targeted outreach is delivered to increase science learning in schools

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Forward

The research shows that many of the traditional approaches and activities aimed at encouraging the most under-represented students into Higher Education are not working. These challenges are further exacerbated in the STEM Landscape where, by the age of 10, many students are already identifying as "Not STEM". The challenge for University Widening Participation Teams becomes how to not only re-engage students with STEM but provide opportunities that can also address the attainment gap of under-represented students. With only 9% of white "working class" boys progressing to university, and over 50% of Universities admitting under 5% of students from low participation backgrounds, fundamental change is needed to the nature of Widening Participation work. It is into this landscape that the NEON Innovation Series was created and the Inspiring Minds project discussed in this report describes the innovative work and partnership of the only STEM outreach project to be included in the Series.

The Inspiring Minds project was conceived in 2017 at Canterbury Christ Church University through a creative and research partnership between the School and College Engagement (SCE) Team and the LASAR Research Centre in the Faculty of Education. From inception to evaluation the project is research-engaged, based in ground-breaking pedagogy designed to enable students to not only understand their school curriculum but develop a rich and deep understanding of the nature and interactions between science and their other subjects. Understanding the impact of the experiences on students' learning, attitudes and self-perception sits at the heart of project with evaluation designed to track students' attitudinal shift and not simply the excitement of a day on campus. Reaching over 400 students with sustained and meaningful engagements across 2 years the Inspiring Minds project continues to develop confident scholars, engaging with big philosophical and scientific questions at the frontiers of current knowledge.

The project starts with the recognition that students are curious about the world around them, eager to create a different, more diverse world, and who with the right support and impetus are willing to step beyond their comfort zone, challenge what they think they know and speak out for their vision of the future. Across six Saturday Sessions (or a summer school) Inspiring Minds undertakes an aspirational approach to Informal STEM Learning – bringing students and academics together to raise their epistemic insight (their understanding of how knowledge and scholarship work, similar to meta-cognition) and then construct their own enquiries. In the spaces of a few Saturdays' students engage with intellectual puzzles about the nature of reality and human personhood in the lights of science, artificial technology, religion and mathematics. They investigate whether a robot can think for itself, the secrets of optical illusions and the power and limitations of our senses to reveal the true nature of reality, whether mathematics is already present in the universe or whether people invented it and how they represent themselves online and the concept of a self-portrait in the modern digital age. This research informs their own STEM projects, where they develop then apply this new, and multidisciplinary knowledge to finding solutions for real world problems before sharing their research, ideas and prototypes at a public showcase event attended by parents, careers, teacher and university professors.

The project reaches out to students who often see STEM and Higher Education as "not for me" and brings them alongside academics, industry professionals, and student ambassadors to create relationships and learning opportunities where their voices are heard. The data and experiences captured in this report do not fully do justice to the work students' put in to addressing the problems and challenges they developed solutions for. Students completing the project are empowered to re-evaluate their relationship with STEM in the classroom and voice their aspirations for the future having engaged in a project that did not speak down to where they were but lifted them up to where they could be.

Finley Lawson & Stefan Colley,

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Executive Summary

Where are we?

- Students start to have low self-identity in STEM from age 10
- The average attainment 8 score of white boys on free schools meals is 29.5 compared to 40.5 for disadvantaged Asian boys
- Women are still underrepresented in the STEM workforce making up only 12.8%
- There is a perception of STEM as for the "elite" reinforced by "masterclasses" and events for "top set" or Gifted and talented students.
- Students disengaged from STEM (despite academic potential) are less likely to self-volunteer or be invited to volunteer by staff to engage with additional learning opportunities.

What are the challenges of STEM outreach?

- University STEM outreach offers are often driven by teacher's curriculum focused requests – this provides students with more of the same, rather than an alternative way to understanding the nature of STEM in HE and the workforce.
- Informal Science Learning focuses on either knowledge application (using knowledge students have) or knowledge generation (creating new, relative to the learner, knowledge) – causing challenges when students from different schools/abilities are mixed in a single session.
- Competition-based activities can reinforce girls' poor self-concept.
- Explicit STEM activities don't encourage under-represented and "not STEM" students to participate.
- Key challenge is creating a learning environment/content that doesn't simply replicate the experience of "school science".

How can ISL re-engage under-represented groups?

- Opportunities provide real-world and/or relevant applications to students, moving beyond replicating a content heavy curriculum.
- Using Big philosophical questions to engage new audiences with the relationship between STEM and the wider humanities.
- Sustained opportunities, over "one-off" intervention enabling students to build relationships, science capital and self-concept/confidence in STEM.
- Epistemic Insight pedagogy focuses on the use of multidisciplinary big questions. Students can access the STEM activities through application of their existing knowledge in science and (as importantly) other disciplines. Preventing students feel they can't engage because of their starting point.

The Project

- Funded by OfS as part of KMPF in Kent and Medway.
- Two outreach activities – sustained Saturday sessions over 6 4-hour sessions (Inspiring Minds: ISL); and residential summer school across 4 days - to raise aspirations around HE and STEM education and careers.
- Partnership between School & College Engagement and LASAR (Educational) Research Centre at Canterbury Christ Church University.
- Students engaging with Inspiring Minds: ISL undertook CREST Bronze Award.
- Public Showcase to display student work and ISL projects returned to schools for further display.

OUR RESEARCH ENGAGED PEDAGOGY is sustained & progressive

Aims of the programme

- Develop HE subject knowledge (STEM), including support for developing subject specific knowledge and technical skills -Students pass their Bronze CREST Award.
- Positive influence on students' intentions to continue into STEM based education and/or careers as well as their perceptions and attitudes to science and HE more generally.
- Increased knowledge and likelihood of application to university..

Introduction and demographics

5 Cohorts

2 Summer Schools

415 Students

92% of students POLAR 3 Quintile 1

91% From Uni Connect postcodes

24 contact hours per student

6 sessions per cohort

74% identified as white ethnicity

Statistically significant shifts in statements relating to

'Future participation in STEM'

- "I would like to have a STEM related job",
- "I would like to study STEM at university"
- "I would like to study more STEM subjects in the future"
- "I am motivated to study STEM post-16"

($p < .001$)

'Importance of STEM in society'

- "Exciting things are happening in STEM"
- "The benefits of science and technology are" greater than the harmful effects"
- "STEM is important for society"

($p < .001$)

'Self-Awareness'

- "I get good marks in STEM subjects (recoded)",
- "I learn STEM subjects quickly" (recoded),
- "I feel confident in my science lessons in school",
- "I can recognize links between science and other subjects"

($p < .001$)

'Educational Aspirations'

- "I am motivated to do well in my studies",
- "I am confident I could get the grades I need for further study",
- "I am confident I could gain a place on a course of my choice if I wanted to"

($p < .005$)

79% agreed they enjoyed taking part in ISL outreach

80% TAKING PART HAD HELPED STUDENTS FEEL MORE SUPPORTIVE OF THE BENEFITS OF SCIENCE AND TECHNOLOGY

84% Passed CREST Award

BRITISH SCIENCE ASSOCIATION

> This helped me better understand the world around me

> *I think it has made me be able to talk to new people without being afraid*

> *You are able to express yourself even more without someone telling you, you can't*

> *I feel it's opened my eyes up to where I wanna go further in life*

Introduction

The UK Government aims to widen the participation of students from under-represented groups in Higher Education (HE). This aspiration includes the goals of doubling the proportion of young people from disadvantaged backgrounds in higher education by 2020 and increasing the number of students from ethnic minority groups.

As part of the National Collaborative Outreach Programme (NCOP) in the Kent and Medway region, Canterbury Christ Church University has developed outreach activities conceived around the latest thinking in Science, Technology, Engineering & Maths (STEM). Two projects, 'Inspiring Minds' and Summer School, aim to enable young people to become confident scholars who can engage with difficult philosophical questions raised by current technological advances as well as to help them develop strategies for coping with the stresses and anxieties of educational environments.

A core aim of these projects is to encourage progression in to HE and moreover, following the publication of Science and the Youth Sector report (Wellcome, 2017), the 'Inspiring Minds' and 'ISL Summer School' projects aim to investigate the impact that Informal Science Learning (ISL) can have on young people's perceptions, attitudes and aspirations around STEM.

ISL and informal STEM education takes place outside the classroom environment and aims to inspire students through hands-on, experience-based activities that can enrich and add value to their school experiences (POS&T, 2011). ISL may be beneficial for young people from disadvantaged backgrounds, who are more likely to find science subjects challenging and unengaging at school (Wellcome, 2012). The STEM focus of the Canterbury Christ Church University projects presented in the following report also brings additional dimensions to the widening participation challenge, where there is also a keen interest in encouraging students from diverse socio-economic backgrounds, and females particularly, to pursue STEM careers (Grove, 2013; ASPIRES, 2013).

It is thought that intensive and engaging STEM outreach can encourage students to consider STEM careers. Current research however shows mixed findings on the impact of STEM enhancement activities on improving the likelihood of those prior mentioned, under- represented groups continuing to study STEM subjects (Banerjee, 2017). However, evidence suggests that conveying the wider relevance of science (a core aim of these projects developed through collaboration with the Learning About Science and Religion (LASAR) team at Canterbury Christ Church University and their work on epistemic insight) can help foster students' interest in and perceived utility of science, which may then encourage aspirations towards sciencecareers (Sheldrake, 2017).

There is also evidence that students are more motivated and can find greater meaning in science education when the learning is contextualised within real world problems. With contextualised learning providing the additional benefit of helping students to deepen their understanding of the nature of science and scientific practices (Allchin, 2013). This was an additional reason for the partnership between the NCOP team and LASAR Centre in the Faculty of Education at Canterbury Christ Church University who examine the impact of curriculum compartmentalisation on student's perceptions of science in order to assess the impact of ISL onunderstanding and perceptions of science.

As part of the wider context around ISL consideration can also be given to 'science capital'. The five evidence-based messages from Archer, DeWitt & King, 2018 suggest that young people's encounters with science are based on anapproach to science capital education and epistemic insight (Nomikou, Archer & King, 2017) and focus on sustained approaches. They also state that the focus should be on connectivity tocreate pathways, progression and partnerships.

The ISL activities created by Canterbury Christ Church University and LASAR were developed in order to give those students with little to no science capital the interest necessary to build these skills through the creation of connections with individuals working in that industry through the activities run with them. Individuals from a widening participation background and in particular those from KaMCOP wards have an unexplained gap between achievement and progression. This potentially may be through a lack of connections creating a lack of social capital and potentially science capital also. The projects delivered by Canterbury Christ Church University endeavoured to help students form those connections.

It is also thought that STEM outreach can have a positive impact on the attainment of more disadvantaged students (categorised by FSM eligibility). Research has shown that achieving a Silver CREST award correlated with a small increase in students' best science GCSE compared to a matched control group (Pro Bono Economics Research, 2016). Some of the participants in this report, those who took part in Inspiring Minds, completed their Bronze Crest Awards.

Using data from repeated measures surveys and interviews, this report summarises the evaluation of these two projects that were run between January 2017 and December 2019 - Inspiring Minds ran for four cohorts, the first starting in January and ending in June 2018, the second starting in September and ending in December 2018, the third starting in March 2019 and ending in June 2019 and the fourth starting in September 2019 and ending in December 2019. The Summer School ran intensively in July 2018 with two groups, mixed and boys. The repeated measures approach forms part of the broader evaluation strategy to track the participants' outcomes, including post-16 participation in STEM for the participants compared with a non-participant matched cohort, and ultimately, progression into HE.

This longitudinal approach will help to build evidence to substantiate whether or not ISL approaches can change the aspirations of young people and whether this can be linked to their future educational and career choices. This need for longitudinal work has been identified in the Wellcome Trust's (2017) Science and the Youth Sector report, which broadly defines the knowledge gap for this evaluation to sit within. This report will be updated as further data becomes available and as more cohorts complete the programme.

Educational Collaboration

In aiming to increase the diversity and participation in HE in general and STEM in particular these projects posed two key challenges that needed to be addressed. The first is to present informal STEM learning in a way that is meaningful and engaging for the students; the second, and arguably more pressing, is that before students can consider participating in STEM in HE they must first be able to see themselves as confident scholars with the critical thinking skills and epistemic insight to engage with and contribute to the discussion. Without first developing their self-concept as scholars changing their perception of STEM in isolation will not change their perception of (STEM at) HE as an attainable goal.

The need to understand and identify ways to overcome these challenges in a meaningful and substantive manner led to the collaboration with the LASAR Centre in the Faculty of Education at Canterbury Christ Church University. Research undertaken by the LASAR team (Billingsley, 2017) examines the impact of curriculum compartmentalisation on students' perceptions of science and in turn how pedagogy influences their expectations about the relevance of science for them. Through the work on these projects and through separate externally funded work LASAR is at the forefront of educational research into the development of a curriculum framework (Billingsley et al., 2019) that challenges students' misperceptions of the relationship between science and other subjects.

By underpinning the development of the project activities with the educational research the aim was to design an ISL strategy that addressed students' identified misperceptions and barriers to engagement with STEM. Therefore, beyond the widening participation agenda the additional research aim of the project was to test whether sustained engagement with big philosophical questions around science and technology would impact students' understanding of/engagement with STEM. The deliberate approach o highlighting STEM beyond the "concepts" delivery seen in schools has been argued to offer one of the most transformative learning shifts with using problem or case-based learning (Allchin, 2013).

ISL Rationale

The Inspiring Minds' curriculum was designed to not only offer and evaluate sustained outreach engagement to improve HE uptake, but also to implement and trial ISL that develops students' understanding of the power and limitations of scientific knowledge as part of a wider research project. The power and limitations of science (sometimes called 'epistemic humility') is both a curriculum objective in science KS4 and a central aspect to the development of epistemic insight.

Further research by Billingsley et al. has highlighted the current compartmentalisation of the curriculum alongside other pressures and barriers within the UK educational system systematically dampens student's interest in Big Questions. When this is understood in connection with research on the importance of science capital (Wellcome, 2017) students from low participation backgrounds are far less likely to have opportunity to develop their understanding of the strengths and limitations of science in real-world contexts and multidisciplinary arenas. Furthermore, those low-participation students are less likely to develop their epistemic insight and associated habits of mind that are required for innovative approaches to teaching STEM within HE, such as the CDIO (Conceive, Design, Implement, Operate) approach to engineering education.

It has been argued (Craven, 2002; Schwartz et al. 2004; Seeker 2005) that teaching about the nature of science needs to be explicit, and whilst this is part of the science national curriculum, it is currently not assessed and therefore remains under resourced within school science teaching. The underpinning concept in developing an ISL curriculum that examines big philosophical questions that bridge science and other disciplines is not to simply provide students with additional scientific *content* but to also *engage* them in the discussion through the support and scaffolding of a research-informed ISL curriculum. The divide between scholar-led and student-led activities enables students' engagement with the nature of science to explicit *and* reflective so that there is opportunity to discussion the nature, power and limitations of the sciences.

In developing outreach activities that also fulfil an ISL agenda a further question is raised as to whether the activities should be focusing on knowledge application or knowledge generation. Knowledge application refers to the students being able to use knowledge they already have, whereas knowledge generation refers to students generating new knowledge (with the newness being relative to the student). In an informal setting with students from multiple schools and ability range in each session the curriculum cannot be based on assumed prior scientific knowledge this can lead to a focus on knowledge generation over application. However, with a key aim of the activities being to foster students' confidence in their abilities as scholars this has the potential risk of leaving students feeling just as disenfranchised and unable to engage as they do in school.

The epistemic insight curriculum approach is innovative through the focus on the use of multidisciplinary big questions, enabling students to engage with both tasks. Students can access the STEM activities (including the CREST award) through application of their existing knowledge in science and (as importantly) other disciplines. The nature of the curriculum provides multiple access points to STEM engagement through a multidisciplinary and "Big Questions" framework. This aims to ensure that students aren't faced with a starting point of feeling unable to undertake STEM research because they have already disengaged from/had a poor experience with STEM at school.

Therefore, in providing a vehicle to overcome misperceptions and barriers to STEM engagement students are presented with an opportunity to both apply their existing knowledge and engage with knowledge generation. For some students the generation is through the development of their STEM content knowledge whereas for others it is through developing their epistemic awareness of the linksbetween and powers/limitations of different disciplines.

In addition, the curriculum for Inspiring Minds (and the Summer Schools) were designed to offer an alternative to the close-ended epistemic processes modelled within formal science learning. Close-ended processes require students to find a single "right" answer to the question/project, this model can lead to students feeling under pressure with a fear of "getting it wrong" that can negatively impact their engagement (Allchin, 2013). The use of Big Questions, and student-led investigation enables students to contribute to the STEM debate and facilitates their entry at different levels by enabling them to develop their own smaller close-ended process/question (through a narrow focus CREST project for example) or to continue to engage at an open-process level where the output draws together approaches or responses from a range of disciplines. The impact of this approach to informal STEM activities is drawn outin the interview responses form Cohort 1 and the curriculum has undergone formative evaluation and development at the end of each cohort in response to the student feedback.

Overview of activities

'Inspiring Minds' is a six-session programme (Table 1), held on a Saturday at the university campus that is targeted towards young people studying in Year 10. Cohort 1 ran over six months with monthly sessions (January to June 2018), Cohort 2 ran over three months with fortnightly sessions (September 2018 to January 2019), Cohort 3 ran over two months (March 2019 to June 2019) and Cohort 4 ran over two months (September 2019 to December 2019).

Table 1
Summary of Inspiring Minds sessions

Session	Session aims
Who am I online?	To experiment with social media profiles. To discuss how the ever-present image of the online self affects and reflects who we are.
Does Siri "just" listen?	To challenge the language used to discuss technology. This session will also work to challenge the assumption that science can or will know everything.
What's the universe really made of?	To help students see maths as a language, and understand how everything we currently know of in the universe living and non-living reflects this language.
Is seeing believing?	To explore how senses, thinking and memory can be manipulated. To examine fundamental parts of what makes us human and where we place our trust.
Show Case preparation event	To plan for the showcase.
Showcase exhibition	To present CREST project and wider Inspiring Minds work to an audience of academics, parents/carers and peers

The programme focuses on building confidence and awareness of STEM in a multidisciplinary context with each session having two parts (1) a guest speaker on STEM in a multi-disciplinary context and (2) a student run session working toward their Bronze CREST award[1] in groups led by trained student ambassadors. Students were incentivised with £30 High-Street vouchers for attending each session.

The ISL Summer Schools focused on high intensity activity, on a residential basis with fully trained ambassadors and engagement in academic and social activities. Two five day residential summer schools (mixed and boys) in July 2018 were based on the Canterbury Christ Church University campus and had up to six academic sessions during the students' stay. The Blood Hound Education Team ran the academic sessions for both Summer Schools focussing on effective car design for landspeed records. Students were not incentivised fortaking part in the Summer School.

Overview of ISL Summer School 2018 sessions

Air Car Workshop – Students designed and build a car from KNEX that were powered by air pumps, cars were tested on a track and then raced under timed conditions. Students learnt about forces, aerodynamics and introduced them to the mathematics around calculating speed.

Model Rocket Car Workshop – Building on the knowledge gained in day 2 students designed and build rocket cars from foam blocks, these cars then had a rocket fitted and were tested over a 100m track for speed and thrust.

Clay space workshop and Escape room. Afternoon trip to Dreamland in Margate

Morning sports events and afternoon awards presentation and departure

Evaluation Methodology

This report (which forms part of a larger, ongoing research project) was designed as a mixed methods research project using a sequential research design to guide the project in terms of framework and analysis. The design incorporates two types of data, quantitative and qualitative, collected for separate purposes. Part of the KaMCOP goal is to evaluate activities with target students. In this report this was done by collecting quantitative data through repeated measures questionnaires collected at the beginning of activities (baseline measures) and at the end of activities (post-activity measures).

Following the collaboration with LASAR on the creation of the ISL curriculum used in the activities, it was decided to collect qualitative data through semi-structured interviews with students who had taken part in activities, to add some level of depth and meaningfulness to this report and the wider research project around the impact of ISL on attitudes around STEM and to further the Faculty of Education's research on how to improve science learning in schools. In addition to the initial repeat measures surveys taken pre and post each cohort, a re-engagement survey was undertaken of all cohorts. In the case of cohorts 1 and 2 this was three and two years respectively after their cohorts finished. Student were asked about the impact of Inspiring Minds on them, their current stage of education current or planned post 16 study choices and engagement with extra-curricular activities.

KaMCOP evaluates activities within the context of the NCOP programme aim to "demonstrate which interventions (in which contexts, and with which learners) have been instrumental in delivering progress, and which could have the most impact in the longer term" (HEFCE, 2016).

The KaMCOP evaluation strategy is aligned with national NCOP evaluation plans and adopts a logic chain approach that aims to devise a structured approach that helps to understand theevidence of what works (or doesn't work), in what contexts, for who and how. This report focuses on the evaluation of outcomes and impact with respect to the outreach participants, however, some process evaluation is also considered where insights are relevant to enhancing outcomes (Crawford et. al., 2017).

The ISL outreach logic chain comprises the background context, the resources to achieve the objectives, the expected outputs, the anticipated shorter-term results and the anticipated longer- term impacts (Figure 1). The context of ISL and details of the activities and resources have been outlined in the previous sections of this report.

The main output is the engagement of target KaMCOP learners and then their project work on completion of the activities. The inputs and outputs are linked to the expected outcomesthrough the assumption that, through participating in the programme, the young people would become more positive about their possible future education and career opportunities in STEM. In the short-term, it wasanticipated that the course would have a positive impact on the participants' self-reported academic aspirations, behavioural intentions (what they intend to do in the future), perceived self-efficacy and attitudes towards STEM.

The aims of both programmes (Inspiring Minds and Summer School) were:

1. Develop HE subject knowledge (STEM), including support for developing subject specific knowledge and technical skills;
2. Support and prepare students to make informed choices about their future;
3. Support personal development.

Collaboration with LASAR provided a fourth aim to change students' perceptions of the nature of STEM by exploring it in real world contexts and multidisciplinary arenas (particularly examined viastudent interviews).

The objectives and the measures used in this evaluation are summarised in Table 2.

Figure 1 Logic chain overview for ISL Outreach

Context

- Informal STEM education takes place outside the classroom environment and aim to inspire students through hands-on, experience-based activities that can enrich and add value to their school experiences

Inputs

- Resources and activites to achieve the objectives include: Content developed with LASAR. Preparation of evaluation resources. Training ambassadors. Creation and production of resources for use by the students.

Outputs

- 90% of students are from KAMCOP target wards. Students work presented at showcase event and farewell BBQ

Outcomes

- Outcomes (i.e. short and medium-term results). Positive influence on students' intentions to continue into STEM based education and/or careers as well as their perceptions and attitudes to science and HE more generally. Increased knowledge and likelihood of application to university. Students pass their Bronze CREST Award.

Impacts

Impacts (i.e. long-term results). In the longer term, and supported through subsequent sustained and progressive engagement, it is anticipated that there will be an Increase in applications to HE (and particularly for STEM) for participants. In the medium-term, participantswill be more likely to chose post-16 STEM routes.

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The evaluation plan was developed to investigate to what extent the activities could be said to have had an influence on the young learners through responding to the following questions:

(1) To what extent might the activities (informal STEM learning in out of school settings) influence the students' intentions to pursue STEM based education and careers as well as their perceptions and attitudes to science and HE more generally?
(2) To what extent could the activities be said to have influenced students' aspirations and sense of self?
(3) To what extent could the difference in the intensity of the activities (i.e. Inspiring Minds Saturday clubs compared to 4 day summer school) be said to influence the participants perceptions and attitudes (e.g. could one approach be said to be more beneficial?)
(4) To what extent is the underpinning epistemic insight pedagogy a contributory factor in changing students' perceptions of the nature of STEM learning and careers?

To evaluate the participants' sense of self, the questionnaires used measures for self-concept (an affective or emotional judgement related to a topic) and self-efficacy (a judgement about 'one's ability to organise and execute the necessary actions to attain a goal') (Beier *et. al.,* 2008).

Table 2
Summary of Objectives

Objectives	Measures
• Participation of KaMCOP ward learners and female students	• Over 90% of participants are from KaMCOP wards • Proportionally higher participation of females
• Participants to report an increase in their academic motivation and confidence	• Increase in level of agreement with statements relating to educational aspirations and motivation measured using repeated survey statements • Students are more likely to say they will apply to HE in the future, measured using repeated survey statements.
• Participants to report that they feel more positive about pursuing STEM related education and careers.	• Students are more likely to say they plan to participate in STEM in the future, measured using repeated survey statements. • Thematic qualitative evidence describing perceived benefits of participating in STEM outreach and how this might link with future educational and career options
• Participants to report that they can see the wider relevance of STEM	• Students are more likely to say they recognise wider social benefits of STEM, measured using repeated survey statements. • Thematic qualitative evidence describing perceived benefits of STEM in society and how this might link with their future educational and career aspirations
• Participants to report benefits to their perceived sense of self	• Students are more likely to agree to statements relating to self-concept in STEM and more general statements relating to self-efficacy, measured using repeated survey statements. • Thematic qualitative evidence describing perceived benefits of STEM outreach for building a positive sense of self.
• Participants to achieve a Bronze CREST award.	• Over 80% of participants to pass Bronze Crest

The methodological approach to evaluation was conceived around repeat measure surveys. The survey questions were firstly derived from the CFE Research baseline survey and questions were included that asked about: educational aspirations, knowledge of HE, likelihood of applying to HE, perceptions of HE, self-efficacy, and demographic questions such as whether they are first generation HE in their family, their gender and ethnicity. Qualitative data from the questionnaire were thematically analysed, guided by the 'benefits to ISL' themes from Wellcome Trust (2017) research (which consisted of interviews with young people). Baseline surveys were completed at the first session and follow-up surveys at the final session with all participants who were present.

Following, the initial evaluation of the first cohort of Inspiring Minds project, additional survey questions were included for Cohorts 2, 3 and 4 and the July Summer Schools to evaluate attitudes towards future participation in STEM, self-concept in STEM and the perceived societal importance of STEM (Table 3). These questions were derived from the 'attitudes towards science' measures developed by Barmby et. al. (2008). For these questions, sub-scales for: self-concept in science; future participation in science and the importance of science were modified to ask about STEM (not only science). Repeated measures were also included for perceptions of HE and self-efficacy. The repeated measures design used a post-activity survey (completed at the conclusion of each project), asked for feedback on the perceived benefits of the project, and included open questions to elicit qualitative feedback from the students on the impact of the sessions.

Table 3
Repeated measures survey questions

Variable	Statements
Educational aspirations	I am motivated to do well in my studies;
	I am confident I could get the grades I need for further study
	I am confident I could gain a place on a course of my choice if I wanted to
Self-concept in STEM	I find STEM subjects difficult (reverse coded)
	I am just not good at STEM subjects (reverse coded)
	I get good marks in STEM subjects
	I learn STEM subjects quickly
Future Participation in STEM	I would like to study more STEM subjects in the future
	I would like to study STEM at university
	I would like to have a STEM related job
Importance of STEM in society	STEM is important for society
	STEM make our lives easier and more comfortable
	The benefits of science and technology are greater than the harmful effects
	There are many exciting things happening in science and technology
Future Intentions	How likely are you to apply to higher education in the future?
Perceptions of HE	It is for people like me
	I would fit in well with others
	I have the academic ability to succeed
	I could cope with the level of study required
Self-efficacy	If I study hard I will get better marks
	I feel that I have a number of good qualities
	I am able to do things as well as most other people
	Setbacks do not discourage me
	I am a hard worker
	I finish whatever I begin
	I feel good about myself

Interviews

Interviews were conducted with 17 students from Cohort 1 of Inspiring Minds over two days. The initial interview cohort was chosen due to the school's willingness to engage with the associated research carried out by the LASAR research hub. Therefore, it is important to note that the students' perception of science learning in school may be indicative of a local rather than generalisable trend. However, the students do represent a range of formal science engagement and academic attainment and their attitudestowards formal science learning are comparable to large scale findings from previous research undertaken by the centre (and nationally). All the students who provided consent were offered the opportunity to take part in individual or paired interviews in the weeks immediately following the showcase.

The key organising member of staff was also interviewed during this period, and the continuedengagement of the school with the outreach team provided the opportunity to interview one of the Deputy Head Teachers in the September following the programme providing richer data about the impact of the project in the short-to- medium term. The qualitative data was thematically analysed with extracts used to highlight the emergent themes. Contrasting results were identified where potentially rivalexplanations emerged.

Students for interview from Cohort 2 were be selected based on their responses to the surveys with the aim of ensuring a cross-section of students' attitudes and engagement with the project. Students from cohorts 1-5 (2018-2020) were re-engaged through invitation in March 2021 (details of this can be found in Continuing Impact Survey).

Results

Participation & data collection

In total, 415 individual young people were registered on the ISL activities with majority (329) taking part across the five Inspiring Minds cohorts (Table 4). 254 students completed both Inspiring Minds and a Summer School, due to the COVID lockdown in 2020 the final session for Cohort 5 had to be cancelled. Overall cohorts 1-4, 91% were known to be from KaMCOP wards and 56% were female. 92% were known to be from POLAR 3 Quintile 1. The ratio of females was highest for the third cohort of Inspiring Minds (62%) and the mixed Summer School (89%). The students were from fifteen schools throughout Kent and Medway and from a range of KaMCOP wards.

In terms of the survey data collection, 244 responses were matched for participants completing both the baseline and the follow-up surveys (Table 4). The number of matched surveys was lower than the total number of participants and the mismatch was due to either: students not consenting to share their data; participants missing the first or last session when the surveyswere completed; or missing (or incomplete) details such that an accurate match could not bemade.

Table 4[1]
Summaries of survey data collected

Cohort	Registered Participants	Completed Baseline surveys	Completed Follow-up surveys	Matched surveys
Inspiring Minds Cohort 1 (Jan 2018)	68	56	44	44
Summer School July 2018 (mixed)	43	40	35	35
Summer School July 2018 (boys)	43	40	36	35
Inspiring Minds Cohort 2 (Sept 2018)	72	56	43	43
Inspiring Minds Cohort 3 (Mar 2019)	76	65	47	47
Inspiring Minds Cohort 4 (Sept 2019)	69	62	40	40
Inspiring Minds Cohort 5 (Jan 2020)	44	41	Lockdown no follow up	-
TOTALS	415	360	245	244

Percentage of Inspiring Minds Students from NCOP target wards

	Not NCOP	KaMCOP	Sussex Learning Network	Total Students	% KaMCOP
Inspiring Minds 1	6	62		68	91%
Inspiring Minds 2	3	69		72	96%
Inspiring Minds 3	3	70	1	74	95%
Inspiring Minds 4	11	55		66	83%
All Cohorts	23	256	1	280	91%

Percentage of Inspiring Minds Students from Q1 (POLAR 3)

	(blank)	Q1	Q2	Q3	Q4	Q5	Total Students	% Q1 (POLAR 3)
Inspiring Minds 1	1	62	1	2	1	1	68	91%
Inspiring Minds 2	1	69	1		1		72	96%
Inspiring Minds 3		71		2	1		74	96%
Inspiring Minds 4	2	55	4	3	2		66	83%
All Cohorts	4	257	6	7	5	1	280	92%

[1] Inspiring Minds cohort baselines collected using CFE format and some students did not consent to sharing their data, hence lower completed baseline numbers. Also, some participants missed the first session but joined later hence lower baselines than total registered for Inspiring Minds cohorts.

Demographics

Baseline surveys for cohorts 1-5 were collected at the first session for 329 participants. 28% of participants did notknow whether they would be the first generationin their family to study in HE. Of those that did know, 46% indicated they would be the first generation in their family to study in higher education[4]. In terms of ethnic identities, 74% of the participants identified as a white ethnicity, 3% of a mixed ethnicity, 3% as an Asian ethnicity, 4% as a black ethnicity, 9%as other ethnicities (the remainder preferred not to say or didn't respond). In terms of gender, 82% of the mixed summer school cohort was female and across the Inspiring Minds cohorts, 60% were female.

38% indicated that they would stay on at school (in sixth form) and 30% indicated they would like to go to an FE college (Figure 1) after GCSE. Overall, 83% agreed that they were motivated to do well in their studies. However, the participants were less confident that they could gain a place on a course of their choice if they wanted to, with 66% agreeing. Three quarters of participants said they were either likely or definitely would apply to study in HE in the future.

Baseline Measures

Baseline attitudes to STEM were collected on the Inspiring Minds cohort 2, 3, 4 and 5 and at the two Summer Schools. The students were largely neutral (didn't agree or disagree) towards the three subsets of statements on self-concept in STEM, future participation in STEM and the importance of STEM in society. The highest agreement was withthe statement that there are many exciting things happening in science and technology (64% agreed). The highest level of disagreement was with the statement 'I find STEM subjects easy' where 20% disagreed.

The responses shown in Figure 2 were numerically coded (where 1 = strongly disagree and 5 = strongly agree) and an average was taken for each of the three attitudes towards STEM subsets. These results contrast with the results from Barmby et. al. (2008) for younger year groups (Table 5). It is worth noting that this is for illustrative purposes only as the research from Barmby et al (2008) had a different methodology (e.g. it asked about attitudes to 'science' not STEM) and a different context to the present research.

The results from KaMCOP ISL (predominately with year 10 students) for self-concept and the importance of STEM in society were consistent with the trends identified in Barmby *et. al.* (2008). That is, these self-reported constructs are observed to decline as the students' progress through the school years. However, the results for future participation in science were higher, perhaps influenced by the application and selection of candidates with keener interests in participating in STEM in the future.

"I feel it's opened my eyes up to where I wanna go further in life, it's interested me more in robotics"

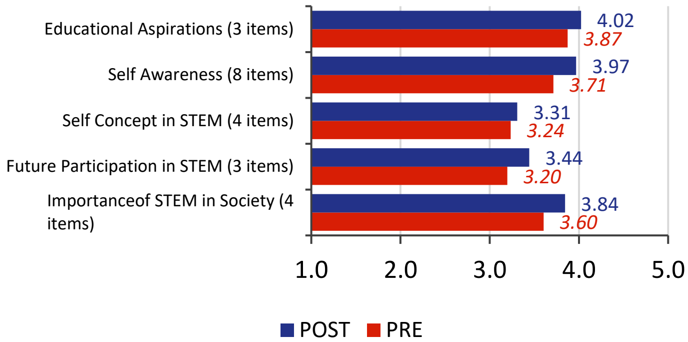

Table 5 *Summary of averaged responses to the attitudes to STEM[2] question subsets*

	Barmby *et. al.* (2008)			Pre KaMCOP ISL	Post KaMCOP ISL
	Yr7	Yr8	Y9	Yr10	Yr10
Importance of STEM in society	3.65	3.45	3.35	3.6	3.84
Future participation in STEM	2.6	2.55	2.45	3.2	3.44
Self-concept in STEM	3.7	3.6	3.6	3.24	3.31

[2] The Barmby study asked about attitudes towards science. Results are contrast for illustrative purposes only.

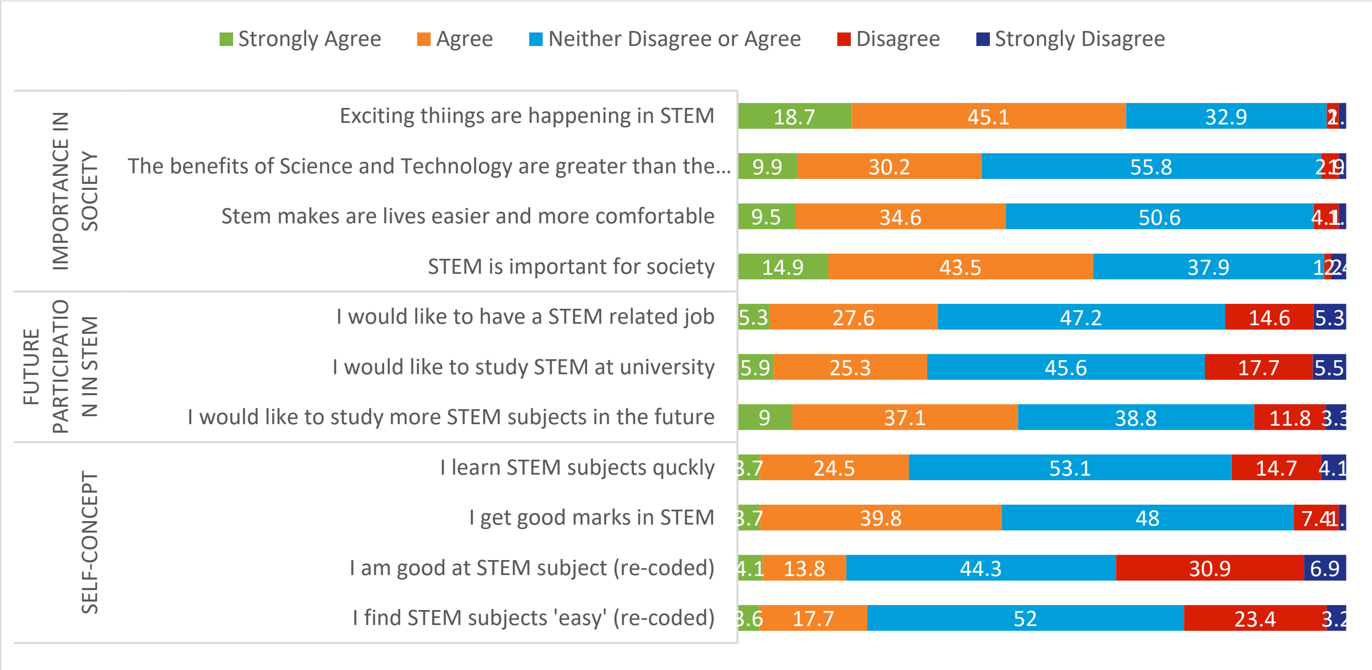

Figure 3
Baseline attitudes to STEM (only collected at Inspiring Minds Cohort 2, 3 and 4 and Summer Schools)

Distance travelled – changes in attitudes

The interventions had the objectives of inspiring change in the ways that the young people perceived their abilities to participate in STEM as well as the potential societal benefits of engaging with the continually evolving challenges of STEM. As part of a theory of change, the analysis sought to understand whether changes in the young people attitudes could be detected and whether any changes (positive or negative) could subsequently be associated with the intervention (this is, changes were not random or would have happened in the absence of the intervention). The self-reported measures from the baseline surveys were compared with the self-reported measures from the post-activity surveys for each individual taking part and the pattern and magnitude of change were analysed for the entire sample to understand the overall trends.

Overall, 245 pre- and post-activity surveys were matched, based on Individual details across the four cohorts of Inspiring Minds and two Summer Schools. The 'attitudes' to STEM questions were matched for Inspiring Minds Cohort 2, 3, 4 and two Summer Schools (n=201), and educational 'aspirations' were matched for all six groups (n=245).

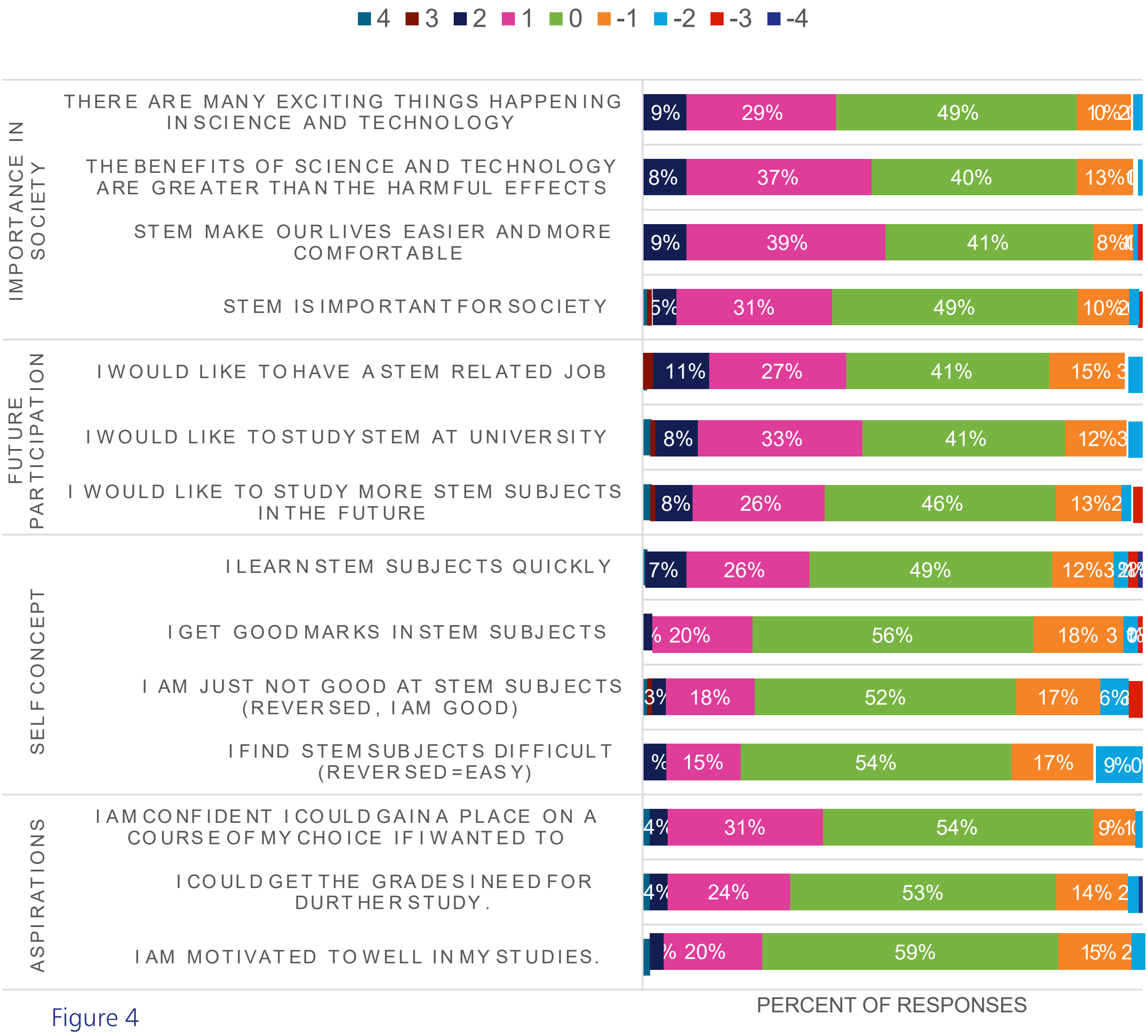

Figure 4
Summary of change in scores for matched individual responses

SPSS (Wilcoxon Signed Rank and Paired T-Test), the change in scores (mean scores and change in mean ranks) was measured. Results (see Appendix B for a summary of the results) showed statistically significant changes in all of the statements within 'Educational Aspirations', 'Self Awareness', 'Future Participation in STEM' and 'Importance of STEM in Society'.

Participants overall displayed a statistically significant shift in statements relating to 'Educational Aspirations' (3 items): "I am motivated to do well in my studies", "I am confident I could get the grades I need for further study", "I am confident I could gain a place on a course of my choice if I wanted to" ($p < .005$).

Participants also displayed overall a statistically significant shift in statements relating to 'Self-Awareness' (8 items): "I get good marks in STEM subjects (recoded)", "I learn STEM subjects quickly" (recoded), "I feel confident in my science lessons in school", "I can recognize links between science and other subjects" ($p < .001$).

Participants also displayed an overall statistically significant shift in statements relating to 'Future Participation in STEM' (4 items): "I would like to have a STEM related job", "I would like to study STEM at university", "I would like to study more STEM subjects in the future", "I am motivated to study STEM post-16" ($p < .001$).

Participants also displayed overall a statistically significant shift in statements relating to 'Importance of STEM in Society' (4 items): "Exciting things are happening in STEM, "The benefits of science and technology are greater than the harmful effects, "STEM makes our lives easier and more comfortable, "STEM is important for society" ($p < .001$).

Two independent variables, Gender and Intensity of activity (Inspiring Minds versus Summer School) were individually analysed for four dependent variables (self-concept, future participation, importance in society and aspirations) using both the independent t-test and the Mann-Whitney U-test. Analysis showed that there were no differences in the amount of change seen in scores based on these two variables between pre- and post- survey measures (consisting of the aggregate change in score for each statement associated with that variable).

Comparing year groups 7, 8 & 9 from a cohort of 932 students across five schools and 3 English regions, Barmby et, al. (2008) found that pupils' attitudes towards science declined as they progressed through secondary school, and this decline was more pronounced for female pupils.

Whilst the results are not directly comparable (due to both methodological and contextual differences), the results from KaMCOP ISL [7] showed that self-reported perceptions of the importance of STEM in society and of possible future participation in STEM were enhanced on completion of the outreach activities (Figure 5). The results for 'self-concept in STEM' were in line with the trend documented by Barmby et. al. (2008) at the baseline and were relatively unchanged on completion of the outreach activities.

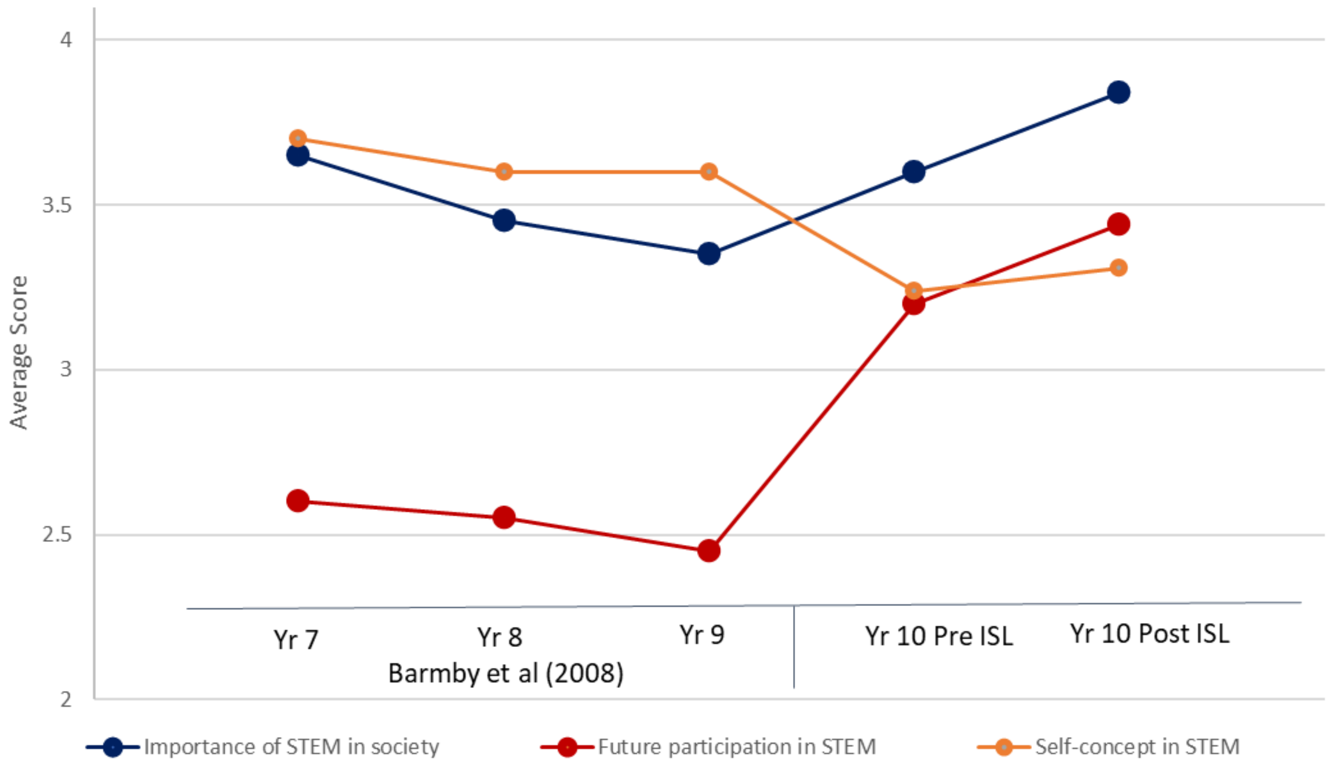

Figure 5

KaMCOP ISL – Changing attitudes to STEM

In summary, the data showed predominantly positive changes in the young peoples' attitudes that corresponded with their participation in the activities and the changes detected were outcomes that were anticipated through a theory of change. Moreover, the changes in self-reported attitudinal measures were consistent across a number of cohorts of young people who participated in activities during different semesters and different academic years. Although the benefits of participating in the activities cannot be confirmed through a control group of non-participants, the achievement of anticipated outcomes and the general replication of positive trends in attitude change over different groups of young people suggests an association with the interventions.

Additionally, 84% of the Inspiring Minds: ISL Students achieved their Bronze CREST Award, a key objective of the programme, raising attainment and changing perceptions of STEM and increasing knowledge of Higher Education and progression routes.

	Registered Students Session 1	CREST Awards passed	% Passed
Cohort 1	68	58	85%
Cohort 2	72	60	83%
Cohort 3	76	64	84%
Cohort 4	69	58	84%
Total	285	240	84%

Evaluative feedback

The feedback gathered via Likert-type statements indicated that the majority of the students felt they benefitted from the informal STEM-based learning (Figure 6), for example 79% agreed that they enjoyed taking part. The responses indicated that 77% of the young people taking part said they had been motivated to study STEM by the ambassadors (77% agreed) while 65% said they had been motivated by the academics. Feedback gathered for Inspiring Minds indicated that taking part had helped students feel more supportive about the benefits of science and technology in society (80% agreed). Whilst 60% agreed that taking part had helped them feel more confident in classroom discussions.

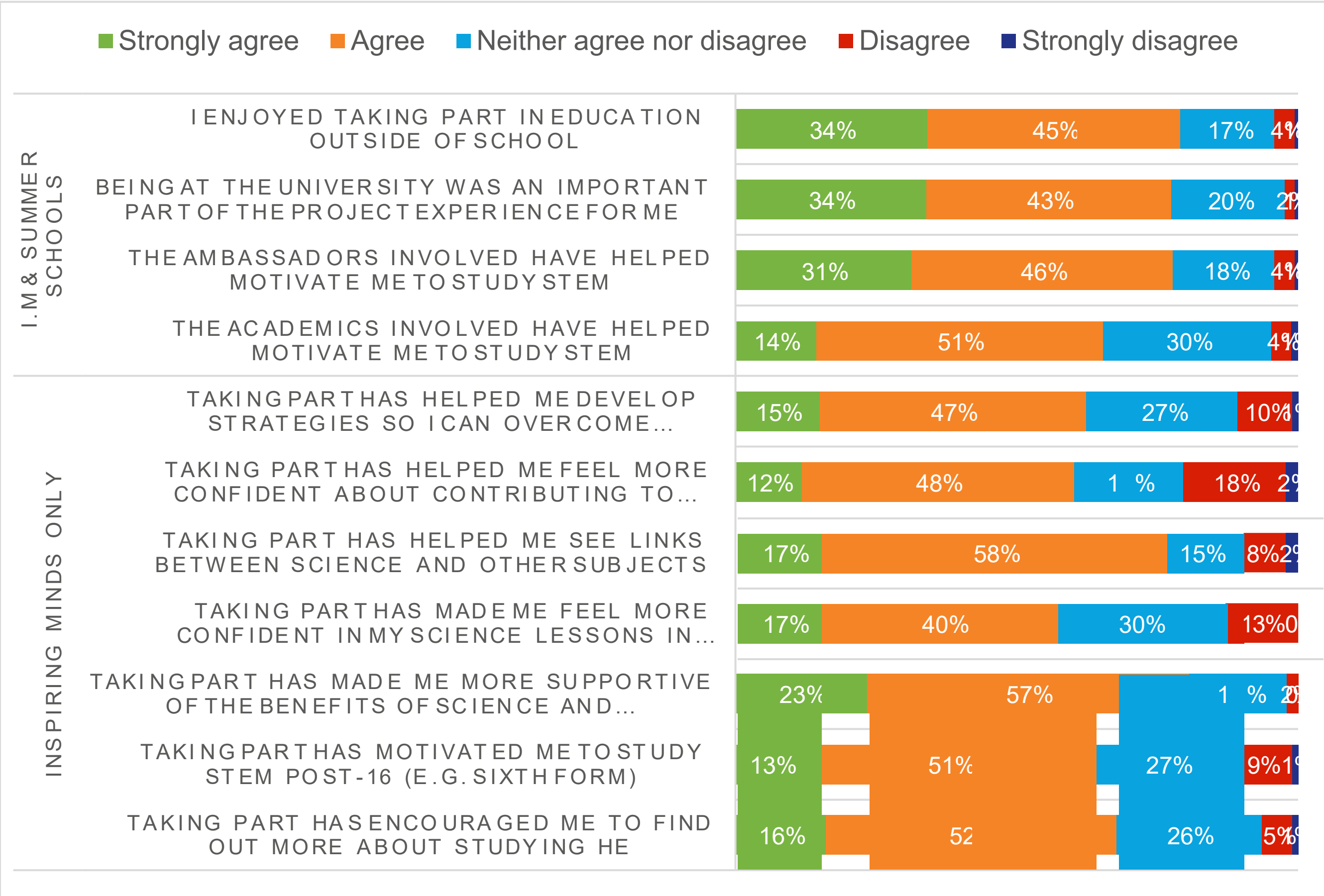

Figure 6

Feedback on the benefits of taking part in informal STEM learning

For Inspiring Minds, the students responded positively to the sessions, in particular sessions 1, 2 and 6. Perceptions of sessions 3 and 4 were more mixed (particularly when contrast over the two cohorts). Responses to sessions 5 and 6 described how some students had experience positive boosts in their confidence through taking part.

The question "What brought you back to the Inspiring Minds sessions each month?", left itself open to answers for example, *'the coach'* or *'my mum'*. However, most of the responses indicated that they came back because of a mixture of the following:

1. The vouchers,
2. Wanting to achieve the Crest award,
3. For fun and enjoyment,
4. Wanting to finish the project,
5. For the experience,
6. For the teamwork and friendships,
7. Partnerships with the ambassadors,
8. Through obligation (e.g. *'the contract'*).

There was also some qualitative indication of perceived benefits to supporting attainment, for example, one student (Cohort 2) responded:

> *"Knowing that it would help my science grade because I want to be a vet"*

and another (Summer School),

> *"The Bloodhound project helped me strongly with my physics".*

The interviews enabled the question of motivation to be explored more thoroughly and also highlighted several students who had cited vouchers as having a big impact on motivation in the survey but gave more complex answers in interview such as

> "it was to prove to my parents I could stick at something"

or

> "I've always wanted to go to university and experience lectures and stuff like that because it was just something for me to think about because no-one in my family has been to university before".

A few students mentioned that the invitation to take part was a big motivator in engaging – it wasn't simply about the opportunity but to engage with ISL/HE but that "I felt wanted". The initial interviews with Cohort 1 students clearly highlighted the complexities of students' motivation and the challenge of running a sustained outreach project at weekends. For many students the vouchers served as the initial motivation to engage with the project, particularly where there was a hesitancy to engage with STEM or felt that there was need to

compensation for taking *"time out from our Saturdays"*.

Additionally, the interviews highlighted that for students where FE and/or HE participation was already an aspiration (irrespective of attitude to STEM) a key motivator was the transferable value of their engagement with the project in relation to their CV or college applications. For some students who weren't already aspiring to HE, engaging with Inspiring Minds enabled them to have a university experience and a common theme for these students was opportunity as a motivating factor.

Finally, a key finding from the interview data was the shift in motivation from pre- to mid-participation when the majority of students who had been initially motivated by the financial incentive shifted to continuing to engage because of the curriculum content. Although further analysis needs to be undertaken with Cohort 2 these initial findings highlight the importance of combining an incentivised activity with a research-engaged curriculum that has been targeted to address identified barriers to engagement.

Perhaps of particular note were the interviews with students who attended both events[3] [8] where they highlighted the symbiotic relationship between the two activities – one students noted that participating in Inspiring Minds had given them the confidence to attend a Summer School, and another it was the combination of Summer School and Inspiring Minds that had inspired their aspiration to attend HE:

[3] Not all students interviewed who attended both events were identified as such during the interview process, so this limits the current data set for this group.

"with the Saturday activities […] you learnt a bit more of the opportunities […] you might do in university […] whereas in the Summer School it's more or less living at the university" [student A];

"I didn't really think about university before but it's really shed a new light on it and I definitely want to go now" [student C].

The response to the questions: *"What has been the most valuable and/or useful thing you have learnt as part of the project? Why?"* and *"How would you compare your learning experience on the project with your learning experience at school?"* were explored to build up thematic understandings of the benefits to ISL that the young participants perceived. In Table 5, the main themes that emerged from the Inspiring Minds data are compared with themes from Wellcome Trust (2017) research (which consisted of interviews with young people).

There was consistency in the overlap of the results from this evaluation with the Wellcome Trust themes. In particularly, teamwork emerged as a strong theme across both the Inspiring Minds and Summer Schools, particularly in terms of the number of responses. There was also a range of sub-themes to 'teamwork', which included describing the benefits from 'collaboration', 'cooperation', 'shared responsibility' and 'appreciating other people opinions'. Finding out about university and the consolidating the possibility of going to university was a stronger theme in the Summer School data, for example:

"by talking to other students to find out their experiences to help me understand what uni is like and the path to uni".

Within the interviews from Cohort 1 repeated themes in discussion of the value of engaging with the project centred around opportunities to be in charge of their learning; undertaking a research project and/or the acquisition of transferrable skills. These benefits were also highlighted by Allchin (2013) as significant features in reforming science education. Whilst the research in this area is discussed in further detail in the research integration section of this report, there are points that are pertinent tomake here as well.

Some students who viewed the opportunity for independent learning as the most valuable outcome of engaging with the project also noted that it had impacted on their learning in school as they had used the skills to complete (non- STEM) homework "*instead of just copying from the text book*" or that they "*hadn't been given something like that before so going away and looking at different sources*" and being critical inbringing the group's research together were newlearning opportunities for the students.

The Inspiring Minds showcase (and preparing for it) was perceived by a number of young people for improving their confidence. The summer schools also supported students with building confidence, as was evident in a number of responses. There was also a possible additional sub-theme where participants described benefits to Learning how to cope - with stress, to not be nervous or scared.

For example students reporting in interview that *"I'm not really one to go up and talk but it's opened me up and I'm a bit more comfortable* […] *in talking to people about certain things"* (student O)*; "I was a bit nervous at first but thenwhen you got in to it, it was easier"* (student I); "*it definitely helped me with my confidence* […] *being able to put myself out there more* […] *and I'd say I'm a lot better at working in teams* [thanbefore Inspiring Minds]" (student H).

The Wellcome Trust's theme of 'Strategic Thinking' (which summarised benefits of reflective and process-oriented learning) was notmanifest in the data and the emergent theme was described as "Understanding the broader context of science in society". The benefits described by the participants related more to therole of science and technology in society, for example:

"This helped me better understand the world around me and current technology."

"It shows how much the earth is indanger and that we need to do things to help the environment".

This theme is of particular interest as it is closely tied to the rationale behind underpinning the Inspiring Minds curriculum with an epistemic insight-led pedagogy. As with the previous theme this is expanded in more detail later in the report but it is notable that there was there was a strong recognition by students in Cohort 1 (and in informal discussions with Cohort 2 students) of a move in their understanding of the nature of science from the narrow concept-led experience at school to the real world, and career related opportunities in science beyond the classroom.

Students spoke to having gained an understanding of how much their daily lives are "*all linked with science"* (student Q); or that that science "*is something better than just sitting in a classroom learning because it had a bigger impact*" (student O) with this wider understanding of science also fuelling some students' aspirations to explore science beyond school

"its definitely allowed me to look at new job opportunities"

[they didn't realise were STEM-related] (student H).

Another Wellcome Trust theme was 'Creative Skills', where the young people had highlighted benefits to being creative and having the freedom to explore ideas. This was contrast with the 'Strategic Thinking' theme where they had highlighted their enjoyment of the creativity behind an activity rather than the systematic building or doing something. This theme was not evident in the data, based on the responses to "*What has been the most valuable and/or useful thing you have learnt as part of the project".* However, when the participants were asked, *"How would you compare your learning experience on the project with your learning experience at school?"* many highlighted how they preferred learning in the outreach environment. There was some concordance with the creative skills theme, particularly around ideas of:

INDEPENDENCE

"At school we rely on the teachers, whereas in these sessions we're independent",

FREEDOM

"you're more free and can use yourown ideas"

FUN

"This was WAY more fun and Practical".

As noted above freedom and independent learning were noted by students in interviews as being key drivers in changing their perceptions of science, and (for some) education at FE and HE level

Initial Interview Analysis

The interviews were undertaken to develop a greater understanding of the educational impact of participating in ISL that used big philosophical questions raised by science and technology as a way to engage students. Through understanding the engagement with ISL it is hoped that we can develop a deeper understanding to the barriers of under-served audiences in engaging with STEM in the formal learning context. Four key themes arose from the student interview data (a) students engaged with the opportunity to undertake independent learning; (b) students' engagement with science through the lens of big philosophical questions; (c) how the style of the science education differed substantially from "school science" and (d) the impact the programme had on their interest in HE.

Independent learning and/or freedom were mentioned explicitly in nine of the interviews. Students frequently commented on the achievement or enjoyment of having the freedom to "do our own research and find out our own stuff" which was often placed in comparison to school science that is "just copying out of a textbook" or "exam style questions you've gotta do it like this, this is the answer, this is the wrong answer, you don't really get to have your own opinion" with one student going as far as saying "I found it easier [on Inspiring Minds] because we weren't being spoon fed but were given the information in ways we understand". For some students The lack of a single answer or method was one of the most challenging aspects of the programme and it was this change in their understanding that there can be multiple perspectives or answers which they took through in to their learning in school. Students' perceptions of the value of independent learning was often linked to the "recipe investigation" approach to school science, and whilst the CREST award facilitated the independent learning that for many students was a positive experience. The opportunity for students to engage in independent learning was also drawn out in the staff interviews that one of the anticipated gains for students was not just meeting the grade but

"that thinking, it's not just chalk and talk and regurgitation at GCSE […] having the confidence to criticise and analyse in the exam".

With the SLT staff member noting that the draw to participate in Inspiring Minds was that it was

"an excellent project for introducing student to higher level thinking and empowering them to be able to access material they wouldn't have normally thought they could".

Students were asked about their experience of engaging with big philosophical questions in both the workshops and as part of their CREST award and the response from the majority of students was an overwhelming enthusiasm for investigating science in this way (in comparison to their experience of school science). 11 students specifically referred to a preference for exploring science in a philosophical and multidisciplinary way and many felt they would be more engaged in science if it was taught in this manner.

"[science] ***is very different*** [at Inspiring Minds] ***like you get more opportunities and experiences like to explore different aspectsof it*** [science]***".***

Students reported greater understanding of the relevance of science as a result of seeing its relevance to big philosophical and real-world questions and being challenged by the diversity beyond physical sciences:

"because this has proved what science actually is, because in school that's what I know science as but then this expanded on whatscience is and that I enjoyed that part";

"like science is so big and I'd never even thought of robots being anything to do with science but it is".

Closely linked to students' engagement with big questions was the comparison with the recipe investigations and engineered narrowing of what is amenable to science through school teaching. Particularly notable were the students who self-defined as "not science" students but who enjoyed the science experience at Inspiring Minds.

"I found it a lot better than like school 'cause you can open up so much more different things with it […] like I'd have to maybe bring some maths in to it for some reasons or like some English just to like look at it from a different perspective".

Many students viewed school science as being about "facts not questions" and that the content/concept focused science curriculum didn't allow them enough opportunity to gain a deeper understanding about understanding howthings work

"I prefer to do more looking into how things work, but that's the same with science I'm just not very good at science".

For many students the opportunity to engage with university style learning on campus and/or ISL has impacted on their engagement with HE opportunities and future career choices. This was evidenced across students who only attended the Inspiring Minds programme as well as those who attended both Inspiring Minds and the summer school. For some students the interest in HE has come through the session topics

> *"I feel it's opened my eyes up to where I wanna go further in life, it's interested me more in robotics".*

Whereas for other students it was the experience of being on campus and/or speaking to the ambassadors "*It's made me want to go to university even more*"; "*I think the ambassadors were really motivating to do it* [go to university]". For students that also took part in the summer school they felt that the combination of Inspiring Minds and the summer school provided a joined up experience of university life *"with the Saturday activities you learnt [...] a bit more of the opportunities [...] you might do in the university and all the resources that are available to you whereas with the summer school it's more or less like living at university"*. With some students expressing that without the opportunity to be involved in Inspiring Minds and the school encouragement to take the 'next step' they wouldn't have considered summer school *"I didn't really think about university before but it's really shed a new light on it and I definitely want to go now".*

The staff responses to motivation in engaging with the Inspiring Minds mirrored those of the students in many ways, with the wider experiences and development opportunities acting as a key driver to engaging with the project. The multidisciplinary nature and framing of the project around big questions were raised by both staff as important anticipated gains for their students.

> "The *opportunity to broaden horizons and then the fact it was engaging with some big questions that involved interdisciplinary work, because this transfers back in to schooland they hopefully start to see the subjects as less separate*";

> *"for year 10 before it gets into focus on exams [...] a last opportunity for them do this bigger thinking which they really need particularly for the new specification GCSE* [...] *those analytical and evaluative skills".*

Staff also reported that students appeared to have had a build in confidence and helping their peers and explain their experience of university to others. This was particularly striking in the interview undertaken with SLT in September where they reported that students who took part in the previous two terms (now in year 11) seem very determined and much more aware of the opportunities when they leave school and "*greater awareness of themselves and what they're capable of*" and that seemed to have a big impact both during the programme and on their behaviour as they have come in to the new school year.

Next Steps

With the majority of interviewed students self-describing as disengaged from science within the formal school setting yet expressing motivation and engagement with STEM in real world and multidisciplinary arenas (through big philosophical questions) and disappointment/frustration that they're "*still always doing this kind of science* [school science]" (student D) and "*that's not what we do* [in science] *in school*" (student F), the initial research highlights the importance of sustained STEM/ISL outreach underpinned by an epistemic insight pedagogy.

If Big Questions do indeed act as hook for student engagement and it acts as a motivating factor for further STEM engagement, students need to be supported to continue to develop their interest and understanding of STEM beyond their experience of the National Curriculum. These projects particularly when taken collectively, offer under-represented students a genuine opportunity to develop their understanding of the nature of science (and STEM related careers) that captures those students not being served by the current curriculum. Particularly important is that it offers a safe (non-grade bearing) space in which students can participate in student-centred and student-led STEM learning.

Whilst the curriculum design was developed in light of LASAR's research with secondary school students, the independent learning, modes of thinking, and bridging questions that students identified as helpful, echo findings by the Higher Education Academy (HEA, 2015) and the Royal Academy of Engineering (RAE, 2014). The engineering habits of minds identified by the RAE include the ability to make interconnections and use the varied perspectives and knowledge of team members to arrive at a solution. The project curriculum enables these traits to be developed or identified by students as relating to the nature of engineering and the CDIO approach in engineering education and industry and in doing so offers the potential to support these students into a more informed approach to participating in STEM HE.

The HEA report identifies key pedagogical principals that underpin high-impact student engaged learning within HE such as 'real world mapping of ideas', students being guided to independent enquiry and STEM learning placed in a meaningful context where students can see the present challenge relating to future applications. What this speaks to is the need to develop methods and opportunities to increase the sustained nature of the engagement and develop ways to bridge the informal outreach experience and the formal experience within schools.

Continuing Impact Survey

Re-Engaging Cohorts 1-5

In March 2021, all Participants who had previously completed Inspiring Minds (Cohorts 1-5) were invited to take part in a re-engagement survey. The questionnaire asked them to reflect on their motivations for taking part, the challenges they experienced and the impact that it had on their science and other lessons in school, as well as any changes they would make to the project in the future.

The schools involved in Inspiring Minds were contacted and asked to pass on an online questionnaire to Participants who had completed Inspiring Minds from 2018 to 2020. Almost a quarter of all Participants who engaged in Inspiring Minds Cohorts 1-5 took part (24%, n=79). All participants received a £30 high street voucher for their time and given the opportunity for an interview later in the year to discuss their views further.

Demographics

A total of 79 participants who had taken part in Inspiring Minds from Cohorts 1 to 5 completed the re-engagement survey. 68% were female, 27% were male, 4% were non-binary/other and the rest did not share their gender. A large proportion of the Participants were from a White British background at 55%, 17% were from Other Asian background, 9% were Black African, Caribbean or Black British, 4% were from Other White Background, Mixed White and Black Caribbean, Chinese and Asian/Asian British – Bangladeshi backgrounds, 3% were from Asian/Asian British – Indian background, and 1% were from Other Black background.

Participants were asked about either their current post-16 studies or their plans for post-16 study, depending on their age and the Cohort they took part in. Of those who were asked about what they are currently studying at Post-16 level, 85% are taking A Levels, 12% taking BTECs and 2% were studying other qualifications. Within that, 43% are currently studying at least one STEM-based subject. From Participants who were asked about their plans for Post-16 study, 81% said that they intend to take A Levels, 11% intend to take BTECs, 3% intend to do an apprenticeship and 6% intend to take other qualifications. Within that, 46% plan to study at least one STEM-based subject.

Participants were also asked about any opportunities they have had to take part in extracurricular activities since completing the Inspiring Minds project. 35% of Participants said they had been given such opportunities, which included clubs at their schools, CCCU Engineering Summer School, work experience, NCS, volunteering and various sports. 65% said that they had not been given the opportunity to take part in any other extracurricular activities since Inspiring Minds, with 13% of these explicitly stating that they feel that this was due to the COVID-19 restrictions.

The most liked element of the project was the fact that Participants were being taught and guided by experts in the field, with 99% of participants agreeing. 97% of participants agreed that they liked the new topics that they were able to explore and the fact that they were able to gain an additional qualification, and 96% of participants agreed that they liked the topic options that were available to them, and that they liked being able to develop new skills. The showcase element of the project had the lowest number of participants saying that they liked it, with 67% liking it and 33% disliking it. Overall, very high percentages of Participants liked all of the elements that they were asked about in the survey.

When given the opportunity to add other comments about the elements of the project that they liked, Participants gave the following comments:

"Gaining a stem qualification to have a more rounded CV as most of mine is arts and humanities based but I enjoy sciences as well"

Participants were also asked about the elements of the project that they found most challenging. In terms of challenges associated with the academic session, the most challenging element was said to be "thinking across my subjects and beyond" with 50% of participants agreeing. For the CREST award, 57% of participants stated that the most challenging element was "investigating topics I was not familiar with. When asked about the challenges of visiting a university, "not knowing what to expect" was rated the most challenging, with 64% of participants agreeing.

Participants were given the opportunity to select which elements they would like to change for future Inspiring Minds projects, focusing on what would make it a better experience for future cohorts. 64% of Participants surveyed suggested that they would like more guidance on how to apply for university and what university life is like, 62% agreed they would like the opportunity to explore other parts of the university, 58% agreed they would like to meet a wider range of Ambassadors from different backgrounds and subject areas, and more freedom in choosing the topics they investigate, and 44% of Participants said they would like to be able to keep in contact with Ambassadors and the university after completing the project.

Impacts of the project after time

When asked about how Inspiring Minds impacted on their experiences during science lessons in particular, a number of themes arose. Many Participants mentioned that they feel they now have a better understanding of science and can see how it relates to real life situations now

"Yes. Having explored science in a non-school environment, I feel that I have a broader understanding of science now."

"It's changed the way I see the things we learn. Now, I think of them in a more practical sense and how it applies to the real world."

and some mentioned that they now find science a more interesting subject, and also that they can see more clearly how it could relate to a potential career path in their future

"I could think about these topics further and how they affected me if I would pursue the subject and helped to make me aware that it can become a big part of people's career"

"Not majorly but as someone who has always loved science I now see science as a possible career choice"

Participants were also asked to reflect on how Inspiring Minds affected the other subjects that they studied at school. A number of Participants mentioned that they now feel more confident to share their thoughts and ideas

"I feel more confident about working on group projects now."

"I think it has made me be able to talk to new people without being afraid"

"Made me feel my point is valid"

that they are more likely to view things from a new perspective

"I no longer do any science lessons as I did not pick these to study further at A-level however I do computer science and this event did give me some interesting ideas as to what to do for my computer science project."

and that going to university may be an option for them in the future

"It helped me feel more confident talking to others, and how university may not be as daunting as I thought!"

Conclusions and Recommendations

Major Conclusions

- Pedagogically grounded outreach activities ensured that the sessions offered meaningful links to National Curriculum content (across a range of subjects), but importantly were also able to provide a significantly different learning environment that supported students re-engagment with STEM.
- The use of Big Questions acted as a hook to engage students in STEM (and HE), enabling them to make use of a range of prior learning whilst also supporting STEM Knowledge generation.
- Participants are better able to understand the relevance of STEM to real-world problems and their own lives, anecdotally supporting them to engage better in school improving their attainment prospects.
- Whilst students were incentivized to complete the Inspiring Minds ISL programme (not Summer Schools) this was part of a wider range of incentives that spoke to their time, work and effort being valued, including the showcase itself (and the professional printing of their research outputs), display of work from across the sessions at the showcase and the time and engagement from the ambassadors and academic staff.
- The sustained engagement and opportunity to form relationships with the student ambassadors was valued by students, with 55% of those resurveyed in 2021 highlighting the opportunity to keep in touch with the ambassadors and university at the end of the programme would have improved their experience.
- 50% of Inspiring Minds Scholars re-surveyed in 2021 reported that learning to think across their subjects and beyond was one of the most challenging aspects of the project – highlighting wider links to the challenges of subject compartmentalisation in secondary schools and the challenges this provides in supporting students to bridge the perception that you are either “STEM” or “not-STEM”.
- 78% of students resurveyed in 2021 provided examples of how taking part in Inspiring Minds ISL had improved their engagement, understanding, or participation in science lessons at school.
- 75% of students resurveyed in 2021 provided examples of how the Inspiring Minds has enabled them to be more confident, open-minded, or better independent learners across their other subjects at school.

Implementation

- Student feedback from each cohort has allowed for iterative evaluation and improvements to be made, and the development of strategies to fill gaps highlighted in the data – for example targeted work developing students’ self-concept in STEM led to statistically significant shifts in these measures with later groups.
- Development of online mentoring and study skills relationship through an online platform in response to the pandemic has provided a model for how sustained engagement could be continued beyond the students’ involvement in the project.
- The content of the Inspiring Minds ISL has been adapted to be deliverable in school through a “roadshow” model. The challenge with this model is that, currently, it continues to only offer “one-off” opportunities to small groups of students and thus doesn’t offer the wider reach and sustained engagement of the Saturday sessions.

Next Steps

- With attainment data recently released for the first cohorts of Inspiring Minds Students further research needs to be done to investigate whether the aspirational shifts resulted in attainment gains.
- Whilst the work with students in year 10 (age 14) and above has been incredibly successful, both our data and wider research speak to the importance of reaching and continually engaging with students as early as possible. Students choosing GCSE/BTEC options in years 8 (age 12) and 9 (age 13), need to have has the opportunity to have had sustained engagement with widening participation projects from, at least year 6 (age 10) in order to start to address some of these entrenched barriers to participation.
- Developing opportunities for past participants to develop continued relationships with the university through eMentoring and the involvement of the scholars with new cohorts, or primary school groups to build their confidence to share their own experiences and see the value and change they can make to others.

Recommendations for UK Widening Participation Practice

- It is imperative that outreach programmes recognise and seek to minimize the multiple barriers to the most under-represented groups engaging with outreach opportunities ranging from barriers to attending events out of school hours or on university campus, to working with schools to personally invite the students who are disengaged and/or perceived as less likely to succeed.
- Widening Participation teams in universities are often located in marketing and recruitment departments (Gartland, 2016), and schools often focus on engaging the students from low participation backgrounds and/or underrepresented groups who are most likely to progress to university. Whilst both of these are understandable given the external pressures on both institutions this can compound the problem meaning that those least like to attend HE (or volunteer themselves) are also the least likely to be chosen to participate the opportunities that could have the most impact. Canterbury Christ Church University and the wider KMPF partners have strived to create relationships with lead teachers in local schools to support a shared vision that reaches both those on track to access HE from low participation areas but also provides opportunities for those most at risk of missing out. But this approach isn't visible at a National Level and further work needs to be done at a policy level to provide recognition (public value) for engaging those least likely to be "success stories".
- In order for the impact of outreach programmes/interactions to fully evaluated three key processes need to be further addressed (1) continued and developed practiced of shared data across institutions (through HEAT) that allows students' engagement journey to be followed through to their destination. (2) programmes need to be able to access funding that allows for future planning and development of experienced, research-engaged teams. (3) to understand the impact, both for attainment and participation there needs to be funding for long-term evaluation enabling projects to span five to seven years to re-engage students and assess the long-term impact of sustained relationships and opportunities.

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Appendix A

Examples of Inspiring Minds Student Curriculum Session Sheets

IDENTITY & TECHNOLOGY

INSPIRING MINDS

WHO AM I ONLINE?

ASKING BIG QUESTIONS THAT BRIDGE SCIENCE & OTHER DISCIPLINES

A portrait is an artwork created about a person or persons which tells us something about them. Is a selfie just another type of portrait? What impact does social media have on how we portray ourselves online - our digital portrait? What other information is being included with your selfie? This raises questions about the impact of technology on our identity and security of our "online selves".

WHAT'S IN A PORTRAIT?

The Ambassadors, Hans Holbein the Younger, 1533, Photo: wikiart

Artists have represented people in portraits for hundreds of years, and not just famous people. Portraits make us ask questions about who these people are, and why they have been captured in paintings and photographs for others to see and consider. Sometimes a portrait doesn't seem to look like the person it is meant to represent, but it may still show us something about that person.

FROM PORTRAIT TO COLLAGE

A collage takes already existing, unrelated materials and puts them together to create a new image. A collage can be made with newspaper clippings, fabric, coloured paper, parts of other artwork, photographs and objects, glued to a piece of paper or canvas. The pieces are arranged purposefully to create different effects on the audience - it might be emotional, or intended to make us think about how all the unrelated images work as a new whole.

Opened by Customs, Kurt Schwitters, 1937-8, Photo: © Tate, London 2018

SELFIES, COLLAGES AND SELF-PORTRAITS

Creating a self-portrait is an introspective process, but the self-portrait itself becomes a representation of ourselves out in the world, and it will be viewed in many different ways. By creating a self-portrait, we can learn more about who we are, and how we want to represent ourselves.
Can a collage be a self-portrait? Can a selfie be a self-portrait? Is it always necessary to present a true image of the person, or are emotions, interests, goals, and dreams just as important? Is the selfie the only way to present yourself on social media?

OVER TO YOU

First, the photo...Take two photographs of yourself with the instant camera. For the first try to be as natural as possible, for the second you'll show how you feel or view yourself. Wait until the end of the session to take your second photo! Then just have fun!

Then, the collage...Use a combination of your 'Insta' photo, the magazines, and a sheet of A5 or A4 paper to create a collage self-portrait.

Not sure where to start? Choose images based on how makes you feel; look for words in the text which are meaningful or represent your interests; pick out patterns within the images or use whole pictures featuring items which interest you. The choice is yours; there is no right or wrong way to do this.

WHO ARE YOU ONLINE REALLY?
Think about your experiences of using technology creatively

- How has this influenced the way you think about the portraits of you on digital platforms and circulating in social media environments?
- How much of yourself do you share online?
- Is the selfie the only way to present yourself on social media?
- Is "who you are" the same online as offline? What about across different platforms (social media/Role Playing Games etc).
- What would your online identity look like if there weren't any camera phones?

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SESSION ACHIEVEMENTS:

- Engage with creative techniques to re-shape the way you represent yourself online.
- Exploring whether the self-portrait truly represents "image" in the modern digital age.
- Understand the difference between digital portrait and digital profile.
- Appreciate that scholars use many methods and some are more scientific than others.
- Art & Design - develop and refine ideas as you work and understand different graphic communication processes.
- English - Listen to and build on others' contributions, and ask questions to clarify and inform.
- Computing - Understand how changes in technology affect safety and ways to protect your online privacy and identity.

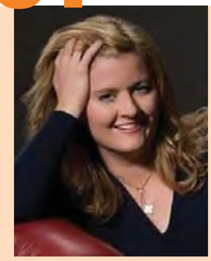
CAREERS TO THINK ABOUT

GAMES WRITER

The story is an integral part of video gameplay experience. Games writers work with the design team moving from concept through to final delivery. They are integral to everything from world design to character development and universe story. Game writers tend to have a love of both English and video games, and are imaginative thinkers who often study creative or script writing at university.

Susan O'Connor

Recognised as one of the most influential and original game writers in the industry working on project such as Far Cry 2, BioShock, and Gears of War. She is known for her innovative storytelling that pushes the boundaries of game content and bridges the line between video gaming and art.



EXHIBITION DESIGNER

Exhibition designers are creative thinkers with excellent design and communication skills. They may work on trade shows and public exhibitions for industry; or cultural exhibitions for museums, galleries and libraries. They are able to design their exhibition to reflect the needs of client and provide an engaging experience for customers and visitors.

Ioanna Gkritzani

Works at Natural History and Science Museums in London where she lets her "imagination go wild, transforming ideas, spaces and objects into installations that visitors can play with and learn from.

SOCIAL MEDIA DEVELOPER:

Social media developers are analytical thinkers who specialise in the technical management of an organisation's social media platforms. They design and create applications to engage their customers, and take their applications from idea to reality. Social Media Developers help to connect the world in ways that have never been done before.

Evan Spiegel

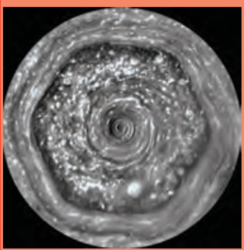
The founder of Snapchat. While studying at Stanford University, he proposed Snapchat as a class project for project design subject. His net worth is still around $4 billion, making him one of the youngest billionaires in the world.

WHAT'S THE UNIVERSE REALLY MADE OF?

ASKING BIG QUESTIONS THAT BRIDGE SCIENCE & OTHER DISCIPLINES

Maths is a language it has vocabulary, grammar and rules for sentences. If we can understand maths as a language it can help us to understand how the world works and how objects in it are connected. This raises questions about how we can make sense of very big and very small parts of our universe, and patterns that appear to arise from chaos.

FROM CIRCLES AND LINES



Source: NASA/JPL-Caltech/SSI/Hampton University

Although seemingly random, nature of full of patterns that follow mathematical rules. From how lightning forks to spiral of a snail shell and even the pattern of broccoli. In fact with just a circle and straight line you can recreate almost every shape in the universe

There is even a mysterious hexagonal cloud pattern at Saturn's North Pole. There are a variety of scientific descriptions of why the hexagon exists, but scientists need mathematics to show why it is a hexagon and not a circle, a star, or any other shape.

UNDERSTANDING NATURE'S BOOK

Maths gives us the tools to explain the fundamental behaviour of the universe from how molecules rotate and vibrate to whether a galaxy spirals clockwise or anti-clockwise. Algebra and equations work to explain complex ideas just like writing systems such as Japanese Kanji.

Kanji can express the difference between listening [聞く] and paying attention to what you're listening to [聴く] just like small variations in equations can explain and link very different concepts.

Source: wikicommons

A SENSE OF SCALE

Some patterns in nature, like the spiral of a pine cone are clear to us, but others are too big or too small to be seen. Just because we can't see the order it doesn't mean it's not there. But can mathematics really describe the behaviour of things from DNA to galaxies? If everything in the universe is describable by mathematics does that mean everything (including us) is following a strict path or can maths describe "chaos"? The short answer is yes, there's a whole branch of mathematics dedicated to chaos theory (also called the butterfly effect). **https://tinyurl.com/chaos-theory-IM**

OVER TO YOU

For your GCSE you will have to create a perpendicular line and bisect an angle - this uses similar techniques to go beyond your exam

Constructing a Hexagon - Use a compass to draw a circle on the page (not too small or this will get tricky!). DO NOT adjust the compass, place the point on the edge of your circle and draw a small arc where the pencil crosses the circle. Now put your compass on this point and repeat to get a third point. Keep going until you have six points on your circle. Connect adjacent points using a ruler to create a hexgon. **Can you build a honeycomb pattern?**

Building a Fibonacci Spiral - The fibonacci sequence starts at 0 or 1 and increses by adding the previous two numbers together: 0,1,1, 2, 3, 5, 8, 13, 21...This pattern forms a spiral also known as the golden ratio which is found across nature and architecture. Use squared paper to build a grid using the fibonacci sequence, theneither free hand or using the compass create a curve across each square until you have a spiral. **How big can you make the spiral? Can you build a double spiral?**

WHERE IS THE MATHEMATICS IN YOUR UNIVERSE?
Think about how you engage with maths without realising

- Find out just how big the minecraft world is or how small your chromosomes are at **scaleofuniverse.com**
- The maths behind CGI **www.mathscareers.org.uk/video/advancing-the-digital-arts/**
- Snowflakes, lightning patterns, the structure of shells and even broccoli are all examples of fractals in nature. **www.maths.surrey.ac.uk/hosted-sites/R.Knott/Fibonacci/fibnat2.html**
- If maths exists throughout the universe did we create it, or discover it?

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Part of the National Collaborative Outreach Programme

Canterbury Christ Church University

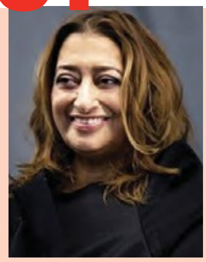
SESSION ACHIEVEMENTS:

- Understanding maths as a language.
- Understand some questions are more amenable to scientific explanation than others.
- Exploring how scale helps us to talk about the full range of size of objects in the universe.
- Appreciating the ordered pattern present in nature from the very small (e.g. DNA) to the very large (e.g. galaxies).
- Maths – Apply ratios to real contexts and model situations mathematically.
- Science – Develop an understanding of the methods of science and understand physical laws/models are expressed mathematically.

CAREERS TO THINK ABOUT

ARCHITECT

Architects have been using mathematical proportions to design buildings form the great pyramids in Egypt to the Gherkin in London Architects are problem solvers who can think and design creatively and then communicate those ideas to a client. They have often studied Art & Design and Maths at school.



Zaha Hadid

Zaha Hadid was a multi award winning Iraqi-British architect, known as "Queen of the Curve". Her buildings can be found from Beijing to Glasgow and she designed the London Aquatics centre for the 2012 Olympics. She was made a Dame for her service to architecture.

BIOPHYSICIST

Biophysicists explore issues where biology and physics meet, which means they're creative thinkers who want to know about relationship between physics and living organisms. They are at the forefront of major advancements in science and medicine, particularly with DNA. They can work for the government, in many industries or doing research in a university.

Candice Etson

Candice Etson trained as a ballet dancer gaining a degree in Fine Arts and Dance. After a few years she returned to university to study physics and gained her PhD at Harvard. She currently looks at how your DNA turns one cell into a muscle cell and another in to a skin cell at the level of individual molecule.

ANIMATION SCIENTIST

CGI animations in films, computer games and scientific modelling are all built using models that are realistic, but can also be processed quickly enough by a computer. Animation scientists work in teams to create accurate models that help us tell better stories.

Tony DeRose

Tony DeRose is an animation scientist at PIXAR. With a degree in physics and a PhD in computer science, he translates arithmetic, geometry and algebra into clouds, smoke and bouncing hair.

DOES SIRI "JUST" LISTEN?

ASKING BIG QUESTIONS THAT BRIDGE SCIENCE & OTHER DISCIPLINES

The EU (European union) are debating how we regulate artificial intelligence (AI) including "electronic personhood". This raises the question how should we understand the advance of human-like robots – should it make us appreciate how very special we are and so, what a long way robots have to go? Or should it make us realise that we're not very special and everything we think is special, will one day be explained by science?

CAN YOU TELL A ROBOT FROM A HUMAN?

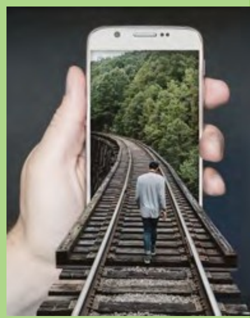
Source: pixabay

Alan Turing designed a method to test whether a machine can fool us into thinking it is human. In order to pass a machine must convince someone (who can't see it) they are talking to a person. In the test humans don't know if they are interacting with a robot or a person. Sometimes the humans on the other end "fail" the Turing test – people think that they are talking to a robot!

Understanding what, if anything, makes us different from machines can help us realise our criteria for saying another entity is a "person".

TECHNOLOGY AND LANGUAGE

We talk about "smart" phones, machine "learning", and Siri & Alexa "listening" to us. But what do we actually mean when we use these words? Is your phone smarter than you?



Source: pixabay

Can it provide information a place you've never heard of more quickly than you? Yes. Can it appreciate that a sunset can be beautiful? Did you answer differently? A similar comparison applies when we talk about the robot "hearing" us or simply responding to sound. Does the robot understand the command?

WHEN IS AI ABOUT MORE THAN PROGRAMMING?

We live in an increasingly technological world where everything from our sleep patterns to our regular commute can be recorded through technology. As technology becomes increasingly more integrated into our lives and habits the boundary between technology and other disciplines becomes increasingly blurred. Can (or should) the programmer be able to answer whether we should use androids in healthcare? Who is responsible when a robot reacts differently in the real world to the lab? Should a robot be granted citizenship and if so when? Can art created by technology have the same value as a work by a famous artist?

To be able to answer these questions (and many others) raised by the use of AI, robotics and technology we must seek to integrate the knowledge and thinking provided by a range of disciplines and understand the power and limitations of each to provide part of the answer.

OVER TO YOU

This is an opportunity to explore how we judge whether something is "human-like" and think about the language we use about technology.

Artificial "intelligence"? -Spend some time talking to Mitsuku - what questions is "she" able to answer easily? Where does "she" struggle to give a human response? https://tinyurl.com/IM-mitsuku
Loebner Prize - Have a conversation with "Millie" about the Turing Test - can you work out whether you are speaking to a robot or human? what happens when you ask about topics other than the Turing test? https://tinyurl.com/IM-turing

ROBOT OR "ELECTRONIC PERSON"?
Think about how you would make the distinction

- What's the difference between hearing, listening (which Siri & Alexa do a lot of apparently), and responding to sound?
- What are the real sticking points that cause challenges for designing robots that interact or "think" like humans?
- If we wait, will technology one day become so complex that consciousness appears? Will there be a "consciousness" chip that engineers can add if it's useful? Or is consciousness nothing like either of these?

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SESSION ACHIEVEMENTS:

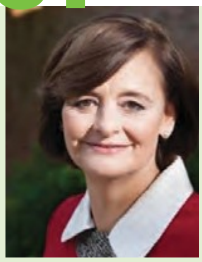
- Critically examine the language we use to describe technology and the complexity of the AI debate.
- Understand that some questions are more metaphysically sensitive than others.
- RE & Citizenship – understand the role of justice in society and the place of moral responsibility.
- Science – understand the power and limitations of science at dealing with ethical issues.
- Computing - apply analytic, problem-solving, design, and computational thinking skills.

CAREERS TO THINK ABOUT

LAWYER

A lawyer provides legal protection for people, and does far more than keeping people out of gaol. Lawyers offer representation (in court) and legal advice to individuals and whole companies. Dealing with court proceedings or small disputes they are often interested in history and English. You can specialise in a whole variety of areas from property or family to the environment there will be something for you.

Cherie Blair



Known professionally as Cherie Booth QC, she is an English barrister. She is married to Tony Blair, the former British Prime Minister. She specialises in employment, discrimination and public law and has represented claimants taking cases against the UK government.

ROBOTICS ENGINEER

A robotics engineer is a creative problem solver, who design solutions to the world's problems. They create new applications for robots and continually find new ways to expand their uses. They work in any industry that can benefit from the technology they create. Engineers typically develop designs, create prototypes and experimental robots, and work on applications that can range from military to medical use.

Melonee Wise

The CEO (Chief Executive Officer) of Unbounded robotics. The company design robots like UBR-1 that can do household tasks such as bringing you drinks, and laying the table. The company is be the one making the first semi-humanoid multipurpose robots that people actually have at home.

MARKET RESEARCHER

Market researchers interview people to find out what they think about products, services or issues. Market research executives and managers usually work for consultancies or in-house marketing/research departments - this can be in practically any industry. The data you collect will normally revolve around what organisations or people buy, need, do or think and the reasons why.

Michelle Goddard

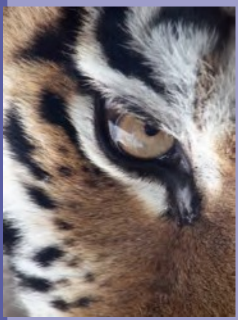
A graduate of the London School of Economics and Political Science, she received her Ph.D. in Law from Osgoode Hall Law School, York University, Canada in 2011 and has a wealth of experience in consumer market regulation and research.

IS SEEING THE SAME AS BELIEVING?

ASKING BIG QUESTIONS THAT BRIDGE SCIENCE & OTHER DISCIPLINES

Science requires observable, objective data. We think reporting on what we see/measure is more accurate and repeatable than reporting on our feelings. But psychologists and neuroscientists point out our senses don't exactly reproduce the reality of the world around us. This raises questions about the difference between our perceptions and 'reality' including how we interpret the physical world.

PERCEPTION



Source: Wikicommons

Some optical illusions occur because of the structure of the eye.Imagine how your view of the world would be different if you had the same eye structure as a dog (the worls is in shades of yellow, blue and grey)… a bee (very poor at detail, but very sensitive to motion)… a rabbit (you can see nearly 360° around you and far above your head, but you have no depth perception for objects close to you).
Find out more: tinyurl.com/IM-animalsight

ASSUMPTION

The brain is a very powerful tool, but to process all the visual information we receive our brain would need to be bigger than a building, and then it still wouldn't be enough. In order to process all this information we (subconsciously) simplify the information we are processing in order to reach decisions at greater speed. It is thought these cognitive "shortcuts" or biases allow us to make decisions quickly, helping our ancestors survive dangerous or threatening situations.

The world you think you are seeing has been constructed in your mind based on your mental model of what's out there! Optical illusions help us study how our mind reates a mental model of reality.

SCIENTIFIC METHOD

Although we often talk of a logical path of "scientific method" scientific discovery is more like a detective story. New discoveries are made with hundreds of people working alone or in groups to share information. Sometimes discoveries happen through mistakes, luck, mathematical appeal or guesswork. A big part of scientific research is thinking creatively about problems, asking new questions that people haven't thought of and finding a way to answer them. It's about stepping outside the comfort zone of existing knowledge and trying something new.

OVER TO YOU

The Stroop Test... In pairs time each other on how long it takes to say the COLOUR of each word in two lists. Use your phone/a stopwatch to record and compare the time taken for each list. If the person does not say the correct colour they will have to repeat the word. What do you think it shows? Is the test useful?

Newton's Colour Wheel...Use a compass to draw a circle about the sixe of a DVD on the white card. Mark the centre point, and draw three lines through the centre so the circle is divided into six spaces. Colour or use coloured card to make the sections red, blue, gree, red, blue, green.
Put a pencil through the centre of the disc and use it to spin the disc as fast as possible. what do you notice about the colours? You are trying to spin the disc faster then your eyes can process the colours

CAN YOU TRUST WHAT YOU'RE SEEING?
Think about the issues of how our sensory data is interpreted

- If you were born and lived on Mars are there any optical illusions that we have on Earth that wouldn't work for you?
- What is the dividing line between perception of reality and hallucination – is it a clear line?
- Which is more important for a scientist – imagination, systematic thinking, or both?

Want to know more? Turn over for careers & curriculum links

Part of the National Collaborative Outreach Programme

Canterbury Christ Church University

SESSION ACHIEVEMENTS:

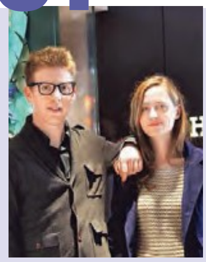
- Be able to relate the idea of cognitive bias to an explanation of why optical illusions work.
- Develop an understanding of the complexity of science in relation to the "scientific method".
- Challenge the claim that we can draw objectively on sensory data.
- Understand the power and limitations of science in dealing with observed data.
- Science – use scientific theories and explanations to develop hypotheses.
- Psychology – explain what causes optical illusions and the role of visual cues in perception.

CAREERS TO THINK ABOUT

VISUAL MERCHANDISER / DISPLAY DESIGNER

Display designers and visual merchandisers use their design skills and creativity to help promote an organisation's image, products and services. Display designers usually focus on displays for exhibitions and events. Visual merchandisers focus on window and in-store displays. People that enter these careers have excellent communication skills and an ability to turn an idea into reality.

Lucie Thomas and Thibault Zimmermann



(Known as Zim&Zou) are French artists who have made displays for companies like Hermes, IBM and Microsoft. They focus on handcrafted objects in a strict move away from computer design.

NEUROSCIENTIST

Neuroscientists study the development and function of the nervous system, which includes the brain, spinal cord, and nerve cells throughout the body. They could specialize in one part of the nervous system, or focus on specific behaviours. You might work directly with patients in hospitals and/or do research in a laboratory or office.

David Eagleman

Directs the laboratory for Perception and Action at Baylor College of Medicine and the Initiative on Neuroscience and Law. He is also a New York Times bestselling author.

PHOTOJOURNALIST

Photojournalists are experts at communication with a deep understanding of how the public will perceive the story through their images. Photojournalist's will take images that are difficult to capture, and convey intense emotion. These will be used in magazines, websites and even books.

Lee Miller

© Telrunya/ WikiCommons

Started as a model for vogue before moving in to photojournalism when she became their official war photographer for World War II. She documented the Blitz of London, the first use of Napalm, the Liberation of Paris and the Nazi concentration camps at Buchenwald and Dachau.

Appendix B

The colour-coding is used to highlight differences in the average change. An asterisk is used to identify any factors with statistically significant differences using ANOVA (or Kruskal-Wallis for the single item 'Likelihood of applying to HE) where there is more than two categories and independent sample t-test (or Mann-Whitney U) where there are two categories (all tests significant at $p \leq 0.05$).

Average Change in score from baseline to follow-up for segmented groups

Factor	Categories	n	Education Aspirations (3 items)	Self-awareness (8 items)	Self-concept (4 items)	Future Participation (3 items)	Importance in Society (4 items)	Likelihood of applying
Cohort	1	44	0.01					-0.14*
	2	43	0.20	0.26*	0.05	0.31	0.42*	0.00*
	3	47	0.16	-0.06*	0.14	0.12	0.02*	-0.18*
	4	40	0.03	0.18*	0.21	0.05	0.15*	-0.17*
	BOYS SS	36	0.06	0.47*	0.03	0.28	0.24*	0.68*
	MIXED SS	35	0.46	0.53*	-0.07	0.50	0.40*	0.39*
Gender	Female	138	0.18	0.23	0.08	0.29	0.33*	0.14
	Male	94	0.08	0.27	0.08	0.16	0.08*	0.08
1st Gen	Yes	116	0.17	0.24	0.03	0.20	0.19	0.12
	No	61	0.19	0.19	0.08	0.24	0.31	-0.16
	Don't Know	58	0.07	0.34	0.12	0.29	0.29	0.18
Science Capital[1]	Q1 (<33.1)	9	0.39	0.36	0.39	0.19	0.28	0.43
	Q2 (<44.1)	10	-0.03	0.26	0.36	0.07	0.15	-0.43
	Q3 (<60.7)	8	0.13	-0.14	-0.11	-0.29	-0.09	0.20
	Q4 (>60.7)	9	-0.29	0.18	0.17	0.21	0.26	-0.50
Disabled	Yes	44	0.20	0.16	0.09	0.19	0.20	-0.06
	No	163	0.11	0.25	0.03	0.19	0.23	0.14
	Not stated	33	0.28	0.38	0.26	0.53	0.30	0.13
Ethnicity	White	198	0.18	0.28	0.06	0.29	0.27	0.14
	Black	9	0.15	-0.04	0.05	-0.33	-0.07	0.22
	Asian	13	0.41	0.26	0.21	0.19	0.09	-0.42
	Mixed	8	-0.25	0.34	0.17	0.33	0.13	-0.50
	Other	12	-0.17	0.18	0.10	0.08	0.22	0.17
School Ofsted	1	18	0.15*	0.07	0.16	0.13	0.28	0.00
	2	142	0.26*	0.27	0.06	0.26	0.24	0.03
	3	75	-0.10*	0.28	0.14	0.33	0.22	0.22
IDACI	1	92	0.12	0.25	0.13	0.27	0.20	0.08
	2	72	0.31	0.21	0.06	0.16	0.21	0.16
	3	36	0.03	0.20	0.04	0.25	0.16	0.00
	4	13	-0.23	0.18	0.04	-0.12	0.20	-0.17
	5	3	0.00	-0.47	0.71	0.50	0.13	0.67
IMD	1	102	0.15	0.25	0.05	0.16	0.22	0.09
	2	72	0.21	0.19	0.14	0.27	0.17	0.11
	3	25	0.15	0.22	0.02	0.36	0.10	0.08
	4	12	-0.22	0.34	-0.23	-0.40	0.25	0.27
	5	5	-0.13	-0.08	0.71	0.33	0.63	-0.60
Uni Connect	Yes	191	0.14	0.22	0.08	0.22	0.20	0.03
	No	53	0.19	0.36	0.05	0.35	0.38	0.26
5 GCSE 4-9	Not Yes	19	0.30	0.43*	0.13	0.23	0.60*	0.20
	Yes	92	0.09	0.07*	0.05	0.23	0.18*	-0.15

Note: the average difference values are calculated for that subset of the data from baseline to follow-up, not from the overall baseline values.

[1]Effect size calculated using d=t/sqrt(N). Where N = total observations, pre and post surveys. Cohen's d: 0.2 to 0.5 = small effect, 0.5 to 0.8 = medium effect, 0.8 and higher = large effect.

Appendix C

Indicative Interview Schedules

STUDENT SEMI-STRUCTURED INTERVIEW SCHEDULE

Part 1 – Inspiring Minds Project

1. Have you had opportunities to be involved in other extra-curricular activities organised by school?
2. What was your initial motivation for joining the Inspiring minds project?
3. **possible pick up of student comments from Q1 on Questionnaire*
4. How much did you know about the topics you've explored before you started?
5. **possible pick up of student comments from Q3/Q4 on Questionnaire*
6. What was the most challenging aspect of the course?
7. Each Saturday was broken down in to three sessions: a workshop, CREST Award Session, and the Mind and Body session – what was your experience of these sessions?
8. How could the project be improved in future?

Part 2 – Wider Impact

1. Would you say that the project has impacted on your experience in science lessons at school?
2. Has it impacted on your experience in other lessons, for example in class discussions?
3. Has the career information or the project experience influenced whether you would consider a science-related career?… **possible pick up of students comments from Q5 on Questionnaire*
4. Finally, the project asked you to take part in learning outside school … **pick up on student comments from Q2 on Questionnaire*

SEMI-STRUCTURED INTERVIEW SCHEDULE FOR TEACHING STAFF

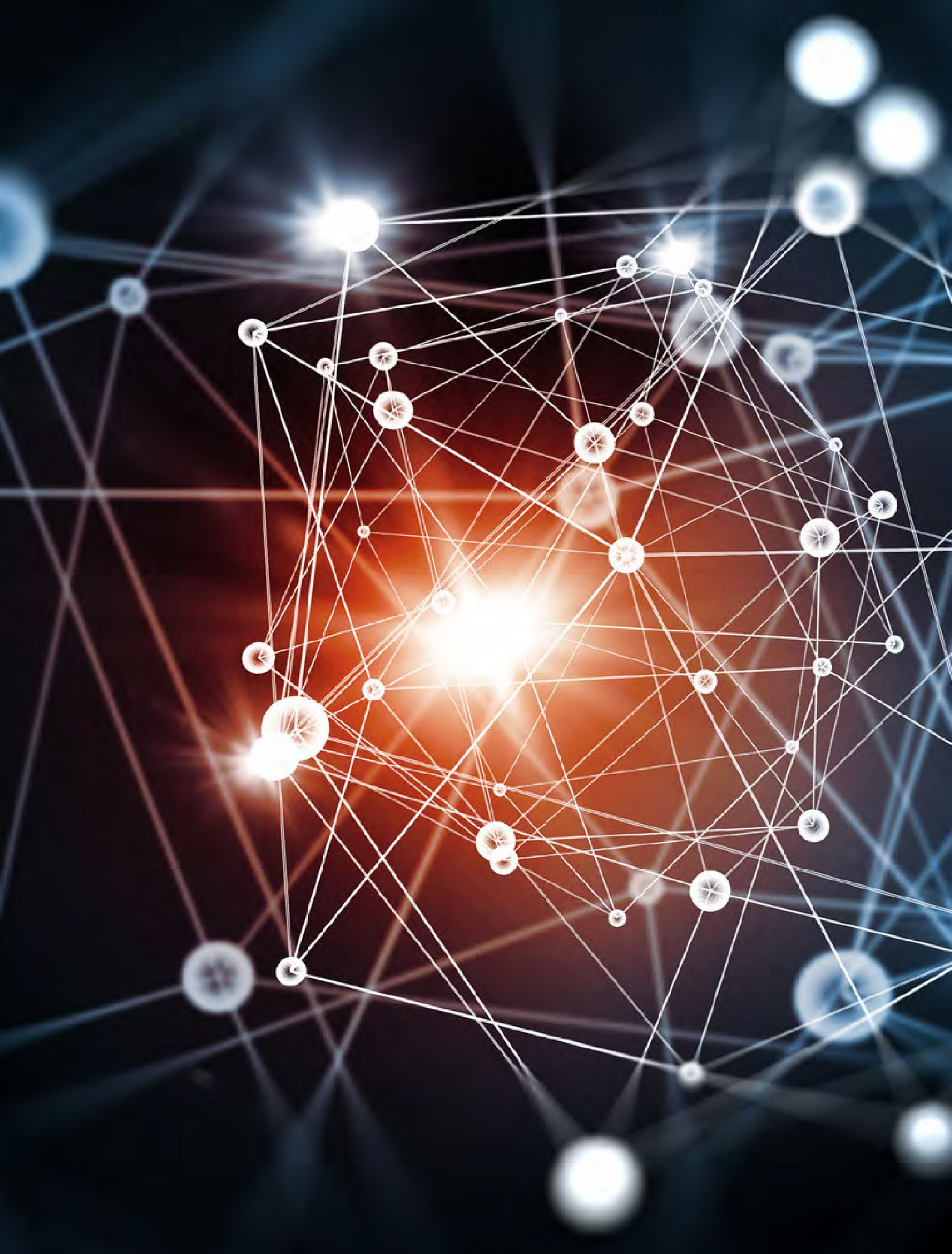
1) How did you hear about the Inspiring Minds Project?
2) Have you been involved in other outreach events by CCCU?
    a. If yes what?
    b. If No why not?
3) What drew you to taking part in the Inspiring Minds Project?
4) What were you hoping your students would gain from the project?
5) What were you hoping you would gain as a school from taking part in the project?
6) Have you or other staff noticed an impact on participating students' attitudes in school …
    a. In science subjects?
    b. More broadly?
7) Have you or other staff noticed an impact on participating students' attainment …
    a. In science subjects?
    b. More broadly?
8) In your view, what worked well and do you have any feedback to help us improve for another time?
9) What – if any - other wider benefits have you noticed by participating in the project?

Table 5

Perceived benefits of Inspiring Minds compared with Wellcome Trust research

Wellcome Trust (2017) themes	Emergent themes	Cohort 1 examples
Learning about specific scientific processes	Learning about specific scientific processes - Developing knowledge and skills. This was particularly for learning about optics in Cohort 2.	*"Probably making the chat-bot, because I learnt how to code and it might be something I want to do as a job when I'm older."; "I have learnt a lot about the brain and eye and how it functions"*
Perseverance	Perseverance - Dedication towards achieving something.	*"That with dedication you are able improve and do well." "We dedicated ourselves to the project - and out of my comfort zone."; "it was to prove to my parents that I could stick at something"*
Teamwork	Teamwork - The importance of teamwork (including cooperating and collaboration), connecting with people and friendships.	*"Communicating with people and making friends";* *"the [CREST] question was perfect for our group[…]it was a really hard question[…] but we all knew little bits about it and we all had our own ideas and shared them"*
Confidence	Confidence - Building confidence.	*"Building my confidence";* *"it definitely helped me with my confidence[…] especially working towards the CREST awards to be able to present my own project[…] being able to put myself out there a bit more"*
Strategic thinking	Understanding the broader context of science in society.	*"This helped me better understand the world around me and current technology."; "this has proved what science actually is […] this expanded on what science is* [from school science]*"* *"like science is SO big and I'd never even thought of robots being anything to do with science but it is"*
Creative skills	Freedom of expression and independence.	*"You are able to express yourself even more without someone telling you, you can't."* *"the freedom to be able to study, where we we had a choice of what we got to study"*
	Learning how to cope - with stress, to not be nervous or scared.	*"How to cope with stress"* *"got me thinking about things I can do to de-stress myself instead of punching things or shouting"* *"quite helpful I think cause I was kinda helping us think about coping with exam stress"*
	Experience of university - Motivation to go to university. This was particularly evident for the Summer Schools and a recurrent theme in the interviews from Cohort 1.	"I didn't really think about university before, but it's really shed a new light and I definitely want to go now"; "it enlightened my sense of going to university more"; "[opportunity to] *go to university and experience lectures and stuff like that […] it's made me want to go to university even more"*

Cohort 2 examples	Summer School examples	Commentary
"Learning about optical illusions was most valuable"	*"The Bloodhound project helped me strongly with my physics"*	Many students were positive about the specific things that had learnt. Whilst creative skills were not mentioned, the development of skills was perceived as a benefit.
	"It gives support and enjoyment, and encourages hard work"	Many students commented that the benefits they felt from dedicating themselves to the project.
"Talking to new people who I never knew and also having this experience and what it's like to do a group project."; "I think team work, we were able to help each other and work as a team."	*"I think the most useful skill was learning how to comfortably communicate and work with other people"*	In addition to developing more positive perceptions of the benefits of teamwork, some also saw benefits to connecting with people and developing friendships.
"To speak to others more confidently"; "The most useful thing was taking part in the showcase, it helped me gain confidence and interact with ne people"	*"Talking to new people. I now find it easier to approach people and have a confident conversation."*	The benefit of building confidence was cited by a number of the students.
"That robots are changing every time people find something now out. This was the most useful thing because I know how things could change"	*"Most things link to science also you can go to university even if you're not rich"*	Strategic thinking was not a benefit explicitly cited by the students. However, other responses showed how the students were developing their understanding of the linkages of what they learned with broader social challenges. Thus, the theme of 'strategic thinking' might be better described from this data as 'understanding the broader social context'
"Inspiring minds is better as it helped me understand science in a fun way"	"I prefer this because it's more interactive and less restrictive"	'Creative skills' were not raised in response to what the participants thought was most valuable. However, when compared with learning in school some identified perceived benefits of more freedom, independence and fun.
	"That being nervous when everyone is in the same situation, is quite pointless."; To not be scared to talk to others and share ideas	Possible sub-theme to 'confidence'
"Seeing what Uni is like which has now made me want to go to Uni"	*"by talking to other students to find out their experiences to help me understand what uni is like and the path to uni"*	Could be a sub-theme to 'strategic thinking' in terms of thinking more strategically about possible options and the potential of university. Also thinking about how STEM links to careers and education opportunities.



www.canterbury.ac.uk/inspiringminds