Demonstrating the importance of curriculum-focussed content: learnings from a collaborative STEM outreach partnership in Second Level Schools in Ireland.

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Keywords: Students, outreach, spatial data, SDGs, recruitment challenges

Abstract

5*S is a STEM outreach programme designed to "attract those not normally engaged with STEM", by introducing spatial data into the secondary school curriculum. The objective was to move beyond the traditional 'school visit' model where a speaker might present samples of their work and instead develop teacher-focussed training and student-focussed content with clear value, encouraging adoption by teachers in their lesson plans. To enthuse the next generation, a team of experts in the geospatial and education fields collaborated to visit schools and inform them to consider a STEM career by bringing interactive content and sharing their own experiences in the classroom. In evaluation of feedback received from over 75 teachers, and workshops reaching almost 19,000 students in 22 counties, teachers expressed that students were more engaged following the workshops and recognised the positive benefits of exposing students to the content. The value of STEM careers, and the role of NMAs was also evident. From a teacher's perspective there was an increase in their own confidence when working with spatial data and a recognition of the potential to enable students to be in charge of their own learning. The value of curriculum-focussed content proposed in this paper was validated, with 98% of teachers indicating that they would use 5*S content again in their teaching and 100% confirmed that they would recommend GIS/spatial data and 5*S to a colleague. This research shows that space, satellites and STEM are relevant to many more than just the traditional subjects.

1. Introduction

In Ireland, as elsewhere, the government, businesses, the education sector and other organisations are mobilising efforts to achieve the United Nations Sustainable Development Agenda by 2030. Students, at all levels, place the environment and a sustainable future as one of their top, if not their top, concern. The Sustainable Development Goals (SDGs) present a suitable way to frame student learning content in multiple areas (McNerney et al, 2023; Brown et al, 2024), simultaneously reinforces the value of spatial data and helping to tackle recruitment challenges (Kolvord and Peterson, 2023) facing the geospatial profession and National Mapping Agencies (NMAs). Spatial thinking is a common skill taught in geography, science, and mathematics classes in post primary schools (Makinster et al, 2013). In Ireland, as in other countries such as Germany, Switzerland and the UK (Dannwolf et al, 2020), students are exposed to spatial datasets early in different core curricula, for example satellite images on climate change. A difficulty arises however in the development of content that is both engaging and accessible, has cross-curricular application, and importantly, is cognisant of limits on instructor time (Bernhäuserová et al, 2022; Wagemann et al, 2022). In developing suitable content and training it is essential for teachers to be able to incorporate new concepts utilising spatial data into their lesson plans by aligning with existing leaning outcomes (Höhnle et al, 2013). The Irish National Mapping Agency (NMA), Tailte Éireann (formerly Ordnance Survey Ireland), began a collaboration in 2019 with academic and geospatial professionals in Maynooth University, Technological University (TU) Dublin, Esri Ireland and the Society of Chartered Surveyors Ireland (SCSI) on a project to showcase spatial data to students: entitled "*5*S – Space, Surveyors and Students – STEM and the Sustainable Development Goals*[1]". The objective of 5*S was to move beyond the traditional 'school visit' model where a speaker might briefly present samples of their own work, and improve on teacher-focussed training (a 'train the trainers' model) with accessible, engaging content that would enthuse and inform and clear value, to encourage its adoption by teachers into their lesson plans.

5*S was funded through the 2019 Science Foundation Ireland (SFI – now Research Ireland) Discover programme, a STEM outreach funding stream designed to "attract those not normally engaged with STEM", and one that particularly encouraged projects with a space context. Applications were reviewed in association with the European Space Education Resource Office (ESERO) Ireland – the European Space Agency's (ESA) main initiative for supporting the early years, primary and secondary education community in Europe through ESERO national offices in twenty-two ESA Member States. In parallel, promoting applications of satellite data and Earth Observation (EO) amongst the wider 'geospatial' community in Ireland had been a goal of the SCSI Geomatics Professional Group since the flooding caused by Storm Desmond in Co. Limerick in December 2015. This event was captured by the Copernicus Emergency Management Service using data from the recently launched Sentinel 1a and supported by other national constellations. Continuing Professional Development (CPD) events showcasing the value of EO data included presentations to other SCSI Professional Groups (PGs), e.g. Rural Surveyors, Quantity

[1] https://5sdiscover.maynoothuniversity.ie/

Surveyors, Mineral Surveyors. This helped highlight some of Ireland’s existing footprint with Copernicus and the European Space Agency (ESA). The Geomatics PG via SCSI subsequently made a submission to the Governmental Department of Business, Enterprise and Innovation’s first *National Space Strategy for Enterprise 2019-2025* (DBEI, 2019*),* highlighting the roles that Chartered Geomatics Surveyors could play in better leveraging Ireland’s investment in EO. Capacity development and information campaigns such as 5*S were particularly relevant, as simultaneously, the geospatial skills shortage became more apparent. In Ireland, the numbers of students studying geospatial courses at third level were also declining, which subsequently led to the closure of University programmes. Earth Observation was also added to the critical skills’ visa list in Ireland (DETE, 2024) - the critical skills list covers skills needs that cannot be met nationally or even at EU level. Geographic Information systems (GIS) and Remote Sensing (RS) were also flagged as critically at-risk skillsets in a recent scoping report for developing the national offshore wind strategy (Wind Energy Ireland, 2024). The Discover programme therefore presented an excellent opportunity to resource a project to scale-up the work being done by volunteers on the Geomatics PG, and to recruit two dedicated staff to offer capacity development opportunities to the wider Chartered Surveyor pool and to improve the promotion of the profession and the role geospatial plays in STEM to the wider public.

2. Methodology

5*S recruits researchers, NMA staff and GIS/RS/land surveyors who use spatial data in their day-to-day work and trains them as GeoMentors. These volunteers join a pool of experts (including core 5*S team members and personnel) who visit schools (either remotely or in-person) and their goal is to enthuse the next generation and inform them about the merits of considering a STEM career. They mostly do so by utilising the 5*S lesson content and sharing their own experiences of work in the field. Since its inception, the 5*S team has developed and delivered a range of activities (both mobile and desktop based) that are designed to make spatial data accessible and inspiring for students. Central to the project’s approach is the delivery of interactive classroom-based workshops, using real-world satellite imagery, digital mapping tools, and Augmented Reality mobile technology (McNerney et al, 2023) to explore themes such as climate change, renewable energy, and sustainable cities. Through these workshops the aim is to enhance cross-curricular key skills in Irish schools. In tandem with the school workshops, the team imparted new skills to student teacher cohorts such as numeracy, data literacy, communication, creativity and independent thinking. Much of the scoping and early 5*S content was conceptualised with the support of qualified teachers, acknowledging the importance of a co-creation approach. Partners in the Department of Education at Maynooth University provided valuable pedagogic guidance at the engagement phase with the initial teacher training cohorts at the University, beginning as a collaboration with undergraduate level (BSc in Science Education Year 3 and 4) before expanding into offerings for the two-year Professional Master of Education (PME).

2.1 Enthusing students and teachers about ‘geospatial’

The core concept of 5*S was to develop a series of ArcGIS StoryMaps and teacher education sessions, introducing teachers and student teachers to many of the key spatial datasets identified by the United Nations Global Geospatial Information Management (UN-GGIM) Committee of Experts as fundamental for tackling the SDGs (Figure 1). Harnessing the students’ enthusiasm for climate action, keeping the focus on the SDGs meant the team could choose the most visually engaging activities with a demonstrated role for EO and satellites. These included extreme weather mapping, flood monitoring, renewable energy, food security or monitoring river pollutants, and showcased the value and application of many of the key datasets. Although inclusion of satellite data was mandatory for every activity due to the space-focus of 5*S, students were free to include in their StoryMaps other UNGGIM datasets, such as Digital Elevation Models (global or national), bathymetry and water bodies, LULC (land use/land cover) data (such as CORINE and NMA datasets), land parcels, orthophotography, point clouds etc. 5*s incorporated data from many of these themes in workshops due to their importance in meeting the SDGs and their value as a visual representation of data (UNGGIM, 2018). A particularly valuable contribution came from one of the initial 5*S partners, Tailte Éireann (the Irish National Mapping Agency), who as an active member of the UN-GGIM Committee of Experts since 2012 - in collaboration with the Irish Central Statistics Office - has played a central role in developing Ireland's SDG data hub. Built on Geohive, Irelands National Geospatial Data platform and hosted at https://irelandsdg.geohive.ie/, this hub provides authoritative information and focussed content measuring Ireland’s progress towards the SDGs. In addition to the wealth of data available data from the Esri Living Atlas and the Copernicus Earth Observation programme, GeoHive was one of the key data repositories that the 5*S project used to introduce the students and student teachers to the linking of data to curricular content.

Figure 1. The Fundamental Geospatial Data Themes defined by the United Nations Global Geospatial Information Management Committee of Experts (UN-GGIM, 2018).

2.2 Exploring the curriculum

Early discussions within the 5*S team centred on identifying the optimal age cohort for the intervention: the point at which students are most actively weighing their career options and making decisions about their university pathway. In Phase 1, the focus of 5*S was placed on the Junior Cycle (years one to three of a six-year post primary school, typically catering for students from twelve to eighteen years old). The Junior Cycle was targeted

because it represents a key decision point for students. Upon completing their Junior Cycle assessments, awarded across eight or nine subjects taken over the three years, students select the subjects they will carry forward into Senior Cycle. While many students also complete an optional Transition Year (TY) before beginning Senior Cycle, it is at this post-Junior Cycle stage that subject and career pathway decisions are most actively made. The two-year Senior Cycle culminates in the Leaving Certificate examinations, which determine students' eligibility and entry grades for their chosen programmes at third level. If the goal of an outreach programme is to best inform students on the role of spatial data and help encourage a relevant geo-career or academic choice, then generally the choices are made at this point. This was not a straightforward decision. Targeting the Junior Cycle meant developing an intervention that could slot into an already demanding curriculum, at a moment of heightened pressure for both students and teachers and5*S content would need to make a compelling case alongside well-established teaching approaches. Therefore, it was decided that the sessions must be developed to align with the requirements of the Learning Outcomes (LOs) of the existing curriculum. The 5*S team therefore began exploring the Junior Cycle curriculum specifications, collaborating with practising teachers on the individual themes and component LOs, and developing a list of topics that best aligned with, and could be best taught using, the data under UNGGIM themes (Figure 2).

The Geography curriculum is the traditional home for a variety of ‘geospatial’ content. For example students in Irish schools might see aerial and true-colour satellite images, explore maps and learn about elevation and cartographic theory thus it is where spatial data would sit best. However, as the goal of 5*S was to promote the role of NMAs and the broader discipline by introducing the students to the wealth of such datasets that can and are being used in industry and research contexts, the curriculum was interrogated afresh. Clear possibilities were identified within both strands of Physical Geography, namely, ‘Exploring the Physical World’ and ‘Interacting with Physical World’ (Fig.2). Examples ranged from geology to urban areas There were also some perhaps less obvious opportunities for utilising spatial data in the Human Geography strand, entitled ‘People, Place and Change’. The final decision was to develop StoryMaps that followed an approaching storm that hit Ireland in 2020 (Storm Jorge). These came from Sentinel 3, and although this satellite is not typically used for weather monitoring, it showed some visually engaging images of this event. The StoryMaps would then proceed into analysis at a more granular level using both Sentinel 1 (SAR) and Sentinel 2 (multispectral) to explore flood mapping, monitoring and recovery. It would allow for inclusion of DEMs and land parcel information among other topics. This content was aligned with Learning Outcome 1.7 “*investigate the formation and behaviour of a significant weather event*”.

The Science curriculum at Junior Cycle was a major justification for establishing the 5*S initiative, providing pedagogic support for the new ‘Earth and Space’ strand of the Science curriculum. On closer inspection however, we found the focus in ‘Earth and Space’ was predominantly on the satellite hardware/astronomical bodies side, rather than the downstream data/analytics element. Although there were topics of relevance for EO satellites such as orbital period etc., it became clear that EO did not best align with the needs of the curriculum under this strand. Subsequent planning identified that the Science curriculum is covered by a thematic umbrella entitled the ‘Nature of Science’, which introduces students to the broader scientific method. Introducing Earth Observation data within this framework therefore offers clear benefits for students across disciplines. Exploring the value of satellite imagery, NMA mapping resources and other spatial data opens up an understanding of why consistent measurement and reliable standards matter in many professions. There were also multiple cross-overs into the other strands of the Science curriculum including the ‘Chemical World’, the ‘Physical World’ and the ‘Biological world’. The final decision was to develop a StoryMap that focussed on the role of spatial data for enabling a renewable energy project, including measuring waterways, wind energy and solar potential. This aligned with Learning Outcome: 1.9 *“differentiate between the types of energy resources produced by the physical world”.*

GEOGRAPHY

L.O	Exploring Phys World	Interact Phys World	People, Place & Change
1	✓	✓	
2	✓	✓	
3	✓	✓	
4	✓	✓	✓
5	✓		
6	✓	✓	✓
7	✓	✓	
8	✓	✓	
9	✓	✓	
10	✓		

SCIENCE

L.O	N&S	E&S	CW	PW	BW
1	✓	✓		✓	
2	✓		✓	✓	
3	✓	✓		✓	
4	✓	✓	✓	✓	
5	✓	✓			✓
6	✓	✓			✓
7	✓	✓			✓
8	✓	✓		✓	✓
9	✓		✓		
10	✓		✓		✓

Figure 2. Learning Objectives identified early in 5*S that could potentially be taught using spatial data. LOs for Geography (left) were predominantly clustered on the Physical side, whereas those for Science were generally cross-disciplinary and also supported by the broader theory of the scientific method.

During early scoping, the team also discussed whether content should take the form of individual StoryMaps, each aligned to a single Learning Outcome or to take another approach. The idea of a follow-on visit model emerged as a possibility. Both the Geography and Science curricula include a Classroom Based Assessment (CBA). CBAs are comparable to a traditional school project or report. For a CBA typically students select their own topic, source the most appropriate data, and research and present their findings in the form of a classroom-based presentation. This process mirrors the scientific method of hypothesis, data discovery, analysis and presentation, as illustrated by the "*Geography in the News*" Geography CBA. This type of student-lead learning is also reflected by successful initiatives such as the Climate Detectives Programme from ESA and formed a major part of subsequent 5*S projects in Phase 2 (2023) and 3 (2026). However, for Phase 1 a single visit using a single StoryMap (or collection of) was considered preferrable.

2.3 Development of engaging student-focussed content

5*S ensures at a minimum that it includes Copernicus satellite data (from Sentinel 1, 2 or 3) in all lesson plans, in addition, it aims to introduce students to many of the other core geospatial datasets. Each StoryMap is therefore a carefully curated sequence of activities that brings a student through this single LO using an SDG to conceptualise it. StoryMaps for each theme can then be combined into a larger StoryMap Collection (Figure 3) and those from 5*S culminate with a sequence of more detailed, self-directed ArcGIS Online (AGOL) self-directed tasks for any student would like to explore further independently. The final stage is where the student is introduced to the most common paths into careers creating and analysing geospatial data and the role of spatial data and the NMA in Ireland. Visualisation tools can showcase the attractiveness of many of the geospatial datasets used, and the core Geography and Science StoryMaps included 3D visualisations and flythroughs of DEMs, spyglass viewers, swipe tools for comparison and others. These helped to illustrate strengths of SAR (Sentinel 1) and RGB (Red, Green, Blue - Sentinel 2) for the greater Dublin area and Dublin Bay.

Swipe viewers were also used to compare pre- and post- flood events for grassland in Glenamaddy, Co. Galway, as well as embedded videos and news articles to help students contextualise the data for each event and location.

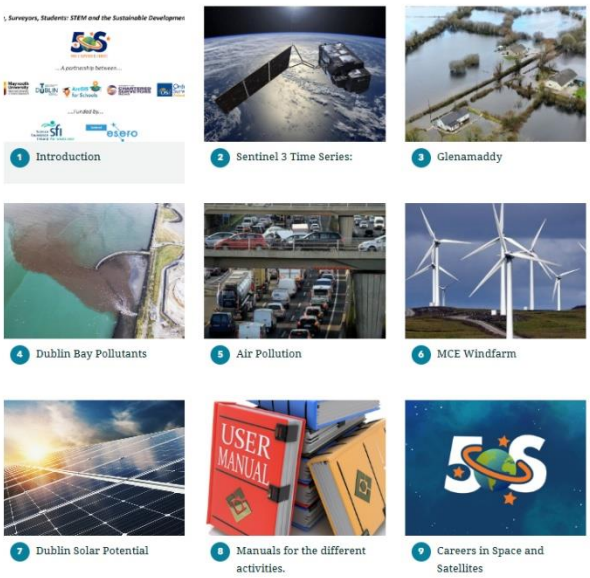

Figure 3. Sample StoryMap collection - introduces the student to the role of earth observation and their role monitoring water and wind. Concludes by demonstrating how spatial analysis can help with optimal siting of solar farms.

As we developed the early content, we continuously sought feedback from participants on what was working, using their responses to refine our offerings and ensure alignment with the curriculum and the relevant Learning Outcomes. A very successful example of community collaboration occurred though the partnership with Skibbereen Heritage Centre to link STEM content with the History curriculum. Focussing on the 1840s at the time of widespread famine in Ireland (referred to as The Great Hunger) is a core element of the History Curriculum and the Skibbereen Heritage Centre is a popular fieldtrip site for students across the province of Munster. This cross-curricular example of spatial data is one of the justifications for 5*S, that data can be used to teach many different subjects. An example outline for Learning Outcomes 3.5 “*examine the causes and effects of urban change in an Irish town or city*” and 3.6 *“identify global patterns”* is presented in Figure 4. Initially the activity lets the student explore how the Earth looks from satellite in the Near InfraRed (NIR) portion of the spectrum and would potentially be their first time learning about this type of energy. The StoryMap then presents the importance of NIR for vegetation analysis and is followed by a demonstration of how common LULC datasets such as CORINE help when comparing landcover across the continent. Subsequently students are showcased using legacy NMA mapping in a Swipe viewer to compare changes between historical paper-based mapping to explore the damage done by a major famine event with small farms/landholdings in a large area completely removed from the map in a few decades. The lesson culminates with an exploration of the role of current satellite-based monitoring systems for predicting and responding to blight risk. The importance of developing interactive, engaging challenges like these was highlighted throughout the iterative project feedback by students and teachers alike. Small challenges to ‘find’ something like houses that are no longer present in a newer dataset, or to ‘measure’ something specific helped keep students engaged. Refinements throughout Phase 1 often included switching from text based StoryMaps to a more challenge-based environment or adding small quizzes to enhance engagement.

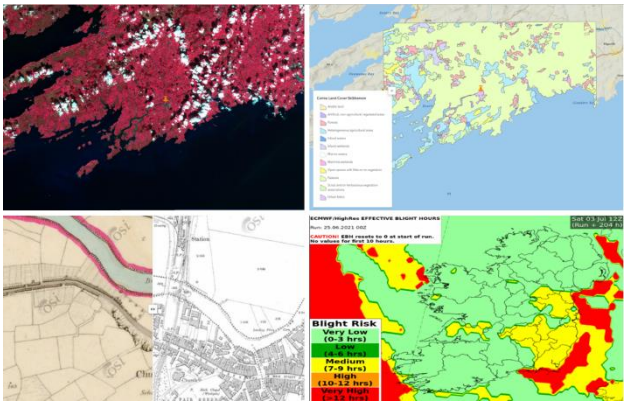

Figure 4. Interactive examples include an explorable FCC from Sentinel 2 looking at an area of a historic blight event, satellite-derived Land Cover data such as CORINE, a swipe tool allowing change from historic NMA paper mapping to be compared and concludes with an introduction to satellite-derived blight indicators.

2.4 Teacher focussed training

Recognising the importance of teacher empowerment and the value of teachers educated in the use of GIS and spatial data feeding into the student cohort as a multiplier of our own efforts, the 5*S team simultaneously prioritised teacher professional learning by offering both in-person and online workshops for teachers and student teachers. These sessions focused on building confidence in the use of digital mapping tools and examples of integrating SDG-related content into teaching practice with GIS used as a tool to promote teacher agency (Brown et al., 2024). Teacher workshops were advertised through national teacher symposia (e.g. Irish Science Teachers Association Annual Conference, Space Careers Week) and also through regional Education and Training boards and Education Centres. Sessions with initial teacher education cohorts at Maynooth University were developed beginning with introductory workshops delivered by staff in the Geography Department. The pilot involved six Year-3 BSc in Science Education groups designing their StoryMaps. These student teachers were supported by the 5*S team to develop materials to teach six different sustainability-related LOs from the JC Science curriculum, encompassing Earth and Space, Chemical World, Physical World and Biological World. Each lesson plan integrated various data sets, multimedia elements, and interactive features such as Web Maps and Timelines. Each of these can greatly enhance the students’ learning experiences. Each group then presented a unique StoryMap focusing on different datasets related to the Junior Cycle learning outcomes. These StoryMaps reinforced understanding of the material but also helped develop students' digital literacy and presentation skills. This pilot began the process of providing these cohorts with an insight into the value of satellite data and an overview of the most easily accessible geospatial data and tools in AGOL. Moreover, they showcased alternative spatial datasets for teaching about the SDGs. This interdisciplinary approach also serves as a model for other initial teacher education programmes, and all of the science-based StoryMaps created as teaching materials are available through the 5*S web page for use by science teachers.

2.5 Logistics and planning delivery of 5*S content and workshops

Early expressions of interest for schools confirmed the need for an initiative such as 5*S. At the outset, questionnaires were circulated through teacher groups and active teacher social media sites (e.g. the Irish Geography Teachers’ group on Facebook) to guide development of the content and the Augmented Reality (AR) digital app. The surveys recorded the teacher experience level, their satisfaction with existing content for teaching satellite themed lessons, and how well served a school was by existing STEM outreach initiatives. 77% of teacher respondents in Phase 1 of 5*S indicated that their school had never received any form of STEM outreach before. The programme was of most interest to more experienced teachers, (defined as those with 10+ years’ experience), potentially because these teachers had more confidence to explore new teaching methods (Fig.5). In addition, teachers indicated whether their schools would have both mobile tablets or computer facilities (or neither) available. Schools were asked whether they could facilitate a double computer lab session of 60–80 minutes. Knowing the time available was essential for determining how much content to place in each StoryMap and ensuring the relevant Learning Outcome could be achieved. Double sessions (i.e. in schools with 40-minute lessons) or one-hour classes, while preferable, were not always possible to arrange, making flexible content planning a priority from early on. Another focus was to ascertain the discipline/curriculum needs – and to identify to what degree a teacher may be expected to deliver both the Geography and Science parts of the curriculum and whether this was of benefit to both. Feedback tended to indicate that more experienced teachers are more comfortable experimenting with new pedagogies.

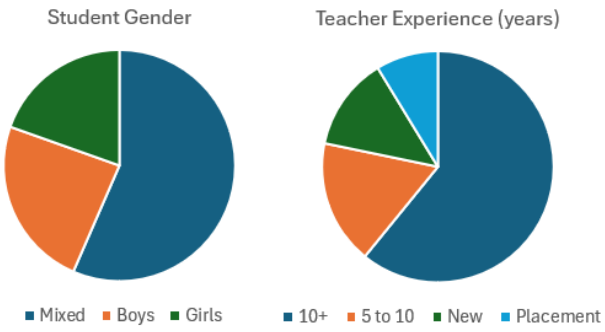

Figure 5. 5*S cohorts engaged throughout Phase 1 - Student profile (left) highlights the focus on female students. Teacher profile (right) outlines the typical teacher cohort.

As an initiative that began at the onset of the COVID pandemic, outreach outperformed expectation with the sudden pivot to completely online offerings in early 2020. It continued to be well received following a transition to a hybrid offering later that Autumn at the beginning of the next school year. The school-based workshops were fully in-person from the start of the school year 2022/23. Our content successfully reached those best aligned with the Discover programme objectives by maximising the proportion of Delivering Equality of Opportunity in Schools (DEIS) (33%), girls-only schools (20%), mixed schools (50%) and visits delivered outside of Dublin (80%).

3. Results and Discussion

The aim of 5*S is to connect students and teachers with real-world applications of satellites, spatial data, and sustainability through engaging interactive tools. By integrating STEM and SDG themes in a relatable and interactive format, 5*S promotes spatial literacy and capacity development while encouraging students to consider a path in geospatial or a related discipline, addressing a growing societal need and one that is very apparent to NMAs and the geospatial community worldwide. Evaluation has been central to the 5*S development process, however one of the most difficult things to gauge is the ‘student experience’. Irish universities require the highest level of ethical clearance to implement any sort of student survey. Tier 3 ethical clearance (required for working with children) is not suitable for any new project, due to the time delays in application procedures and subsequent delays if refused or returned for revisions (would result in the loss of six months or more of research time on a one- or two-year project). 5*S therefore applied for and was approved for Tier 2 ethical approval in 2020 (SRESC-2020-2399213) and revisions were applied and approved in 2021 (SRESC-2021-2434644). This tier permitted interviewing practicing teachers using the outreach programme and enabled the exploration of the potential of satellite data and GIS as a teaching tool, their suitability for teachers on the junior cycle curriculum, and reasons for student uptake.

3.1 Evaluation methods

Before launching interventions, baseline and benchmark data were collected to support comparative analysis of the effectiveness of the project, measuring teacher satisfaction with existing content for teaching elements of the curriculum and their understanding of spatial data, satellites, the SDGs, and the Copernicus programme. To further assess success, mixed evaluation methods were adopted, including quantitative surveys and participant feedback. The results represent feedback from over 75 teachers, and our workshops reached almost 19,000 students in 22 counties. 68% of school visits over the three years were in either mixed or single sex girls’ schools. A focus on the latter allowed us to reach significant numbers of one of our priority groups. The partnership with Maynooth University/TU Dublin enabled targeting schools in the DEIS programme and approximately 30% of workshops took place in DEIS schools and an over-representation of the 28% of post primary schools that are part of the DEIS programme nationally.

3.2 School Workshop and STEM Outreach

Post-event questionnaires and rankings/free text were used and the teacher acted as a proxy to measure student enjoyment/level of engagement during a 5*S session. All scores ran from 1 (no benefit) to 5 (maximum benefit), see Table 1. Those teachers surveyed agreed that their students benefited significantly from being exposed to GIS as a teaching tool with an average answer across the 3 years of 4.25/5 with a slightly greater impression on the Geography students but still significantly appreciated by the Science cohorts. The teachers agreed that student engagement was better than average with a score of 3.5/5, with similar engagement levels for both Geography and Science students. Teacher opinion was very positive on the benefits of exposing the students to GIS in their subjects with a score of 4.8/5 averaged across the two subjects. The students’ understanding of spatial data and satellites was greatly improved, particularly for the Science cohort, who might be considered as outside the traditional ‘geo’ sphere and not as familiar as Geography students. This is reflected in the lower score here of 3.71 out of

5. Finally, the value of STEM careers, and the role of NMAs and value of a career as a surveyor/geospatial/geodesist were also demonstrated to the students and an appreciation of the importance of STEM careers was quite high at 3.74/5. Scores were ranked from 1 to 5 with 5 showing the greatest positive impact.

Teacher benefit	**Progress after 5*S**	
	Before	After
Teacher Skills (Science)	2.43	4.14
Teacher Skills (Geography)	2.00	3.43
Student benefit (Teacher Opinion only)	**Post 5*S**	
	Science	Geography
GIS as a Teaching Tool	4.43	4.86
Benefit of Exposure to GIS	4.57	5.0
Student Engagement	3.50	3.5
Importance STEM Careers	N/A	3.74
Understanding of Satellites	4.43	3.71
Understanding of the SDGS	4.43	3.71

Table 1. Progress measured across three years: 2020 – 2022 for teachers (top) and students (bottom) – using teacher opinion only.

3.3 Teacher and Initial Teacher Training

In parallel to delivering JC content to pupils the 5*S team led 'train the trainer' work packages, focussing on practising teachers and student teachers. No student teacher feedback is reported here and all feedback presented is from practising teacher questionnaires only. For a detailed discussion of the role of GIS for teacher agency from the focus group see Brown et al. (2024). Table 1 demonstrates that average teacher confidence in teaching with space and satellite data increased from 2.21 to 3.78 following a 5*S workshop. Free-text feedback was also very useful for refining content and tracking impact, with multiple references made by teachers (Table 2) to both the cross-curricular nature of spatial data/GIS/satellites, and to the benefits of highlighting the role of real-world data for their specific learning outcomes. The value of this data for enabling students to control their own learning was also apparent, due to the engaging, interactive nature of the StoryMaps.

Cross-curricular	*"Cross-curricular relevance, lending itself to improved Geoliteracy"*
	"Opportunity to see the importance of Geography in the real world."
	" So many cross curricular links"
Real world data	*"Opportunity to bring real world data into the classroom"*
	"Fantastic to have access to real world data for students to experience and explore."
	"A wealth of information that can be accessed."
Student-lead learning	*"I would like to get 3rd year students thinking about the BT Young Scientist and how they could use the data available from [satellites] to design a research project and solve a problem."*
	"I spoke to students after the workshop and they really enjoyed it even though they didn't ask many questions as they felt awkward on line."
	"This is a great app. My students all enjoyed it as did I, because it really made them learn. They enjoyed it because it wasn't just reading books and it was interactive.

Table 2. Teacher comments post workshop – teachers generally recognised the cross-curricular nature of spatial data and the value of real-world data for student engagement.

Phase 1 evaluations indicated, however, that the relevance of adding 'location' to data - that is, making it spatial - was not always immediately apparent across different curricula. Data that were clearly valuable and of relevance to a teacher to help them to understand trends, predict change and compare scenarios were often considered 'just a map' when presented visually - something that was particularly noticeable during the Science teacher workshops. Here, data represented in a GIS ceased to be considered as 'data' whereas in events where teachers from a range of subjects were present and taking parst in a collaborative discussion on this data, the connection between the data and how they were represented was clearer. This mismatch in terminology was one of the reasons why fewer subject-specific terms were utilised as the project progressed, preferring terms such as 'surveyors', 'key skills', and 'digital data/literacy' when discussing outputs – something that had more cross-disciplinary commonalities in terms of terminology. These key skills are explained in more detail in the technical discussions developing our supporting Augmented Reality app, *SatelliteSkill5* presented in McNerney et al. (2023). For example, here SAR backscatter image is showcased and we explain how these are measurements of microwave energy, and flood threshold maps are binary data and clusters and classes used for LULC.

3.4 Potential impacts

The resources developed and activities undertaken have supported the integration of spatial data into everyday classroom learning, often for the first time. In addition, the links between satellite/EO technology and the pressing sustainability issues affecting communities in Ireland and beyond have been made clear. The visibility of 5*S and recognition have also continued to grow. The Irish Government selected the 5*S project as a national case study for its voluntary review to the United Nations on progress towards achieving the 2030 Agenda for Sustainable Development, highlighting its ability to connect education, research, and public engagement in support of the SDGs in a multi-partnership approach (GOI, 2023).

Initiatives such as 5*S can also potentially strengthen public awareness of the value of spatial data and satellites/GIS, better highlighting the importance and role of the NMA. It can support economic growth by supplying industry with highly skilled and much needed STEM graduates, improving the recruitment pipeline by building human capacity through upskilling teachers and future educators in spatial data and digital skills, ultimately encouraging greater uptake of STEM subjects at post-primary and university levels. It will strengthen Ireland's contribution to its national SDG commitments, particularly SDG 4, which calls for inclusive and equitable quality education and lifelong learning opportunities for all. Increasing gender representation on STEM courses at third level is a major focus of 5*S, with the potential to improve recruitment on geo-related programmes, while also addressing the human resource challenges facing the geospatial sector and NMAs worldwide and aligns with existing initiatives promoting NMA resources by the European Spatial Data Research Group (EuroSDR) such as Bucher et al. (2022).

3.5 Sustaining momentum – continuing the initiative with uncertain funding streams.

The value of curriculum-focussed content proposed in this paper was validated, with 98% of teachers indicating that they would use 5*S content again in their teaching and 100% confirmed that they would recommend GIS/spatial data and 5*S to a colleague. Post-workshop, the teachers generally recognised and appreciated the cross-curricular potential of spatial data and

particularly valued their new understanding of the wealth of data available through resources such as the Sentinel satellites, Geohive and Esri's Living Atlas. The results confirm an increase in teacher confidence in related fields, while improving student engagement. However, a significant issue with outreach or engagement initiatives such as 5*S is maintaining momentum, and keeping the project going after the funding has stopped. As the core team move onto new projects, 5*S has been working to ensure it can continue as funding is reduced, if not completely removed. A number of routes can potentially help to mitigate this:

Infrastructure: Firstly- each school visited is now set-up for AGOL as part of the 5*S contact process. Free AGOL logins for all Irish schools was a €500 million donation from the 5*S project partners Esri Ireland to the Irish school system in 2018 and this is replicated and available in many countries across Europe. It is therefore possible for NMAs to approach teachers and create and deliver content for their own potential workshops. The presence of a motivated, 'Geo-friendly' teacher in each school who can become the AGOL administrator is also extremely valuable as this teacher can then add additional colleagues and advocate for the use of GIS in related/different fields, particularly those who may want to experiment with GIS using the cross-curricular content created. The benefit of leveraging an existing, well-maintained cloud-based infrastructure such as AGOL in terms of ease of school set-up, quick sign-ups and longevity of content cannot be overstated.

Class Plan Template		
Title of Class: *Explore the physical world - Soil*		
Aim: *Gain knowledge on Arc/Visualisation.*		
Required Components		
1. Learning Outcome Targeted: *Exploring the Physical World (location/interrelationship)*		
2. SDG Targeted: *No. 15 Life on Land*		
3. Satellite Datasets Incorporated: *Sentinel 2a (multitemporal)*		
4. GIS Layers Incorporated: *EPA Soils, S2 LULC, Water Layers, Ice Sheets*		
5. GIS Tools Utilised in Activities: *Swipe images, Widgets, Survey123 Quiz*		
Proposed Schedule		
Time	**Student Activity**	**Student Answer**
0:00 – 0:10	*1. Use layers to find the area that has flooded in recent years.*	*What is the answer they should provide at the end of the activity? Is it a number? Find and write down a real world object? Is it a line they draw on the map?*
	2. These will get progressively more advanced during your session	……
	3. ……	……
	4. ……	……
	5. ……	……

Figure 6: Sample lesson plan developed by the MSc GIS/Remote Sensing students to include spatial data, satellite images and interactive challenges.

Volunteers: Embedding some sort of outreach in University programme assessments can also help: The GeoMentor programme was embedded in two third level modules at Maynooth University and TU Dublin. "GY638 GIS In Practice" in Maynooth included StoryMap creation and school outreach as a component each year and the ABC programme serving Dublin DEIS schools partnered with the 'Students Serving the Community' programme in TU Dublin and paired final year BSc Geographic Science students with local schools in Phase 1. These initiatives were particularly useful due to the online component during the COVID pandemic but were harder to maintain thereafter. Despite this, having a willing and geo-proficient cohort who develop new StoryMaps each year is of value, and such cohorts are required each year to develop a short lesson plan (Figure 6), using a minimum number of spatial datasets and targeting different learning objectives from either Geography or Science. Students use Sentinel 2 and swipe viewers, interactive quizzes etc to show students the relationship between soils and geology, historic ice sheets, present day. They must time the activity for a single class, with a minimum number of required datasets and activities. The GeoMentor stage was also formally embedded in the assessment practice for the initial teacher education programme. These students bring the pedagogic expertise to creation of the StoryMaps that the more geo-students are lacking, and vice-versa. Similarly moving into Phase 2, the call for volunteers was expanded beyond GIS/EO to include more geomatics/survey focussed companies across Ireland, and this has had some success also although not reported upon here.

Content: In addition to the StoryMap collections hosted on ArcGIS.com, there is clear value for pursuing collaborations with the Esero offices, in particular by focussing on well-branded initiatives that will attract students and teachers such as the ESA Climate Detectives programme. Spatial data and EO imagery are both well suited for the explorative approach promoted in Climate Detective programme. 5*S supplied a use-case for students across Europe using content and data developed. Online school repositories (such as www.scoilnet.ie in Ireland) are also valuable sources of content for teachers, so wherever possible these could be populated with geo-content to widen the reach and user uptake can be tracked.

4. Conclusions and Future Work

5*S has demonstrated that space, satellites and STEM are relevant to more than the traditional subjects. It has the potential to be used as a teaching tool in a wide range of subject matter and showcase the importance of the NMA to schools and teachers. It has been successfully demonstrated that maps and satellite data can be effectively used for teaching across multiple Junior Cycle subjects with over 150 interactive StoryMaps developed in Phase 1 alone. GIS is discipline-independent and it has been shown to enable the teaching of Science classes in a new, exciting way by looking at relevant content simply by adding location to existing data. Whether through use of curated content, or supporting student exploratory research for CBAs, 5*S has demonstrated that it can easily be expanded to encompass History, Computer Science and Maths. However, in terms of timing although Junior Cert is ideal to target students at the age when they are choosing Senior Cycle options, a non-examination year may have even more potential as teachers are more likely to experiment and have more freedom in the timetable. One acknowledged limitation of Phase 1 is that the student experience was captured indirectly through the perspective of their teachers. This was a pragmatic decision, taken considering the time required to secure ethical approval for data collection with participants under the age of 18. In Phase 2, we pursued Tier 3 ethical approval, enabling us to engage more directly with student experience. Those findings will be reported in future publications, as Phase 2 concluded in March 2026. Future iterations of the project will continue to prioritise the direct inclusion of student voices in the evaluation framework.

Finally, one of the learnings from the evaluations in Phase 1 was to explore a 'repeat visits' model, creating a link between each GeoMentor, whether from NMAs or industry for deeper engagement. These repeat visits can simultaneously reinforce the value of careers in Geo related industries, showcasing uses of satellites, GIS and the SDGs and while demonstrating the value of a STEM career as the GeoMentor will profile their own career and interesting projects.

Acknowledgements

This publication has made possible with the financial support of Research Ireland (ex-Science Foundation Ireland) and the European Space Education Resource Office (Esero) Ireland under grant number 19/DP/7171. Tier 2 ethical approval was granted under (SRESC-2020-2399213) and (SRESC-2021-2434644) for teacher questionnaires and interviews.

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