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Subramaniam Ramanathan,
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Iowa State University, United States
Nyet Moi Siew,
Universiti Malaysia Sabah, Malaysia

*CORRESPONDENCE
Cornelia Connolly
✉ cornelia.connolly@universityofgalway.ie

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A stratospheric mission – design of a conceptual framework to bring weather balloons and STEM into the classroom

Cornelia Connolly[1,2]*, Patrick Johnson[3], Kevin Johnson[4], Mary Fitzpatrick[5] and Derek T. O'Keeffe[2,5]

[1]School of Education, College of Arts, Social Science and Celtic Studies, University of Galway, Galway, Ireland, [2]Lero, SFI Centre for Software Research, University of Galway, Galway, Ireland, [3]School of Education, Faculty of Education and Health Sciences, University of Limerick, Limerick, Ireland, [4]Department of Nursing and Midwifery, Faculty of Education and Health Sciences, University of Limerick, Limerick, Ireland, [5]School of Medicine, College of Medicine, Nursing and Health Sciences, University of Galway, Galway, Ireland

Introduction: Integrated STEM education makes learning relevant and applicable, blending the mindset, skillset, and toolset necessary in developing a depth of understanding for science, technology, engineering and mathematics.

Methods: Based on the theoretical framework of Kelley and Knowles the 'Spaceship Earth' project was designed to engage primary school children in 4th class (ages 9 and 10 years old) in real-world project-based experiments in the classroom that are used to develop collaborative problem-solving skills and a framework for asking and answering scientific questions. This project involved researchers from two Universities and the Irish National Meteorological Service working collaboratively on a high-altitude balloon mission.

Results: High-altitude balloons have an established track record of safe and effective use in weather forecasting, astronomy, and STEM outreach. During the project lifecycle the children devised experiments that they launched to the stratosphere using the high-altitude balloons. Once the experiments returned to Earth, the children engaged in analysis and discussion about their experiments that extended and deepened their learning.

Discussion: This celestial project framework represents a new dawn of innovation for STEM education and public engagement.

KEYWORDS

STEM, outreach, high-altitude balloons, education, STEMM

1. Introduction

There has been a growing awareness that excellence in Science, Technology, Engineering and Mathematics (STEM) is necessary to help students develop the knowledge and skills required to live and work in the 21st Century (Stohlmann et al., 2012; Hallissy et al., 2013; English, 2017). In Ireland for example, high quality STEM education has been recognised as essential in promoting economic growth and ensuring future success for the country (DES, 2016a). Nonetheless it is important to recognise that the acronym STEM has been contested in recent years. The benefits of integrating the arts across all STEM disciplines and changing the acronym STEM to STEAM (Science, Technology, Engineering, Arts and Mathematics) has been widely discussed (Henriksen, 2014; Connor et al., 2015), as well as STEM (Science, Technology, Engineering, Mathematics and Medicine) (Church et al., 2021).

This study focuses on the original acronym STEM for the primary reason that in Ireland the DES (2016a) do not incorporate the arts or medicine in their report 'STEM Education in the Irish School System.' The STEM Education Review Group (DES, 2016a) identified the need for significant reform in the area of STEM education in Ireland, acknowledging that the quality of STEM education in the current 1999 Irish primary curriculum is insufficient (NCCA, 2005; Burke, 2014; Gilleece et al., 2020; Perkins and Clerkin, 2020). The report provides recommendations and proposed actions to advance STEM education across all Irish primary and post-primary schools, stating that technology should be used to transform science and mathematics lessons from a 'teacher-directed model to a facilitatory or constructivist model' (DES, 2016a, p.41). Similar international reports published in the US (Granovskiy, 2018) and Australia (Education Council, 2018) provide similar recommendations. Considering these reports, the aim of this research was to design an intervention to enhance STEM teaching and learning at primary level.

The most recently published Primary Curriculum Framework (NCCA, 2023) offers a promising opportunity for a revision and revitalisation of STEM education to all primary school students in Ireland. The goal of the 'Spaceship Earth' project was to inspire, engage and educate teachers and young children about STEM through launching high-altitude balloons from Ireland to the 'Edge of Space,' as space is seen as an amazing way to enthuse people about STEM. Furthermore given the current justifiable concern regarding climate change, the ability of high-altitude balloons to carry student projects & cameras to the edge of space (~30,000 m), allows reflection on the uniqueness of our blue planet – Spaceship Earth.

The future of space science depends on our ability to attract and engage students into STEM disciplines (Hodson, 2003; Jones et al., 2012; Larimore, 2020). Authentic, hands-on experience with space applications enhances engagement and learning in the STEM disciplines and can help to attract disinterested students to STEM careers (Baran et al., 2019). On researching the STEM education at primary level and tools currently available to teachers, it was decided to design an outreach programme to explore the impact a high-altitude balloon experiments on students' learning and evaluate the potential of these to enhance STEM education in primary school setting. This paper will propose a conceptual framework to guide primary school teachers and educators interested in building an outreach STEM education programme.

2. Background

The STEM Education Policy Statement in Ireland states that STEM education should "enhance STEM learning for learners of all backgrounds, abilities and gender" (DES, 2022, p. 2). Additionally, the Action Plan for Education 2016–2019 (DES, 2016b) states as a goal the need to "enhance the quality of learning experiences for young children" (p. 28). They also stress the desire to significantly reduce the gap between low achieving students in literacy and numeracy in DEIS and those in non-DEIS schools and the need to increase the take up of gateway subjects: Physics, Chemistry and Mathematics to the highest level (DES, 2016b). The Delivering Equality of Opportunity in Schools (DEIS) programme was set up by the Irish Department of Education in 2002 (Fleming and Harford, 2021) to provide to equality of opportunity in schools irrespective of socio-economic location of the school or students.

The overarching goal of STEM education is to empower the current generation with innovative mindsets (Education Council, 2018; Granovskiy, 2018). Many educators intuitively believe that curriculum integration produces greater learning outcomes in school subjects (Czerniak et al., 1999; Frykholm and Glasson, 2005). They believe that curriculum integration helps teachers and students develop a deeper understanding of STEM disciplines, while also allowing them to see STEM as an interconnected entity with a strong connection to the real world. Unfortunately, according to Cuadra and Moreno (2005), there is a gap between how STEM subjects are taught in schools and the knowledge, skills, and beliefs required for true STEM education.

Reducing the gap between current instructional practices and the actual skills needed for STEM education is contingent upon the expertise of STEM teachers to successfully transition from the departmentalised model of teaching to an integrated teaching model (Furner and Kumar, 2007). Spaceship Earth aims to engage teachers, and students, in an inquiry-based learning activity that transcends the traditional subject boundaries that exist between STEM disciplines whilst simultaneously empowering teachers with the skills and expertise necessary to independently implement such cross-disciplinary STEM activities in the future.

In recent years, several universities and agencies around the world have commenced operating a high-altitude ballooning programme with the aim of sparking participants' interest in STEM (e.g., University of Maine; Overlook Horizon Inc.; European Space Agency). These programmes were all in some way inspired by 'Project Icarus,' an MIT-based project, which in 2009 launched a camera into the stratosphere that demonstrated that reaching the stratosphere was technically feasible, affordable, and of significant interest to the public (Gallucci, 2017). The Spaceship Earth project was design to ignite interest from children and schools at primary level, as well as engaging students' parents and the wider communities, in an attempt to highlight the importance and relevance of STEM in our lives while simultaneously enhancing the learning experience of the participants.

2.1. The Irish primary education curriculum

In Ireland, STEM education has undergone immense change in the last number of years – for example, policy change with the Action Plan for Education 2016–2019 (DES, 2016b) and then more specifically the Digital Strategy for Schools 2015–2020 (DES, 2015) and the STEM Education in the Irish School System reports (DES, 2016a, 2022). The post-primary education system in Ireland consists of a three-year lower secondary period called the Junior Cycle, followed by a two- or three-year upper secondary period, called Senior Cycle. Curriculum has been reformed in the redesign of the Junior Cycle and Senior Cycle subject specifications (NCCA, 2017, 2018). Aligned with this STEM policy changes has been the growth in the informal learning environments evidenced in leveraging industrial internship opportunities, as well as community involvement such as coding clubs, the Coderdojo movement (Davis, 2013) and CSforALL Summits (Cooper et al., 2014).

The curriculum in Ireland provides a broad learning experience for children in their first 8 years of school (children typically start primary school at age 5 years). The Primary School Curriculum (1999) outlines the syllabus content and outcomes of children's learning, aiming to develop each child's potential to the full; encourage a love of learning and help children develop skills they will use all their lives. It is designed to nurture the child in all dimensions of his or her life—spiritual, moral, cognitive, emotional, imaginative, aesthetic, social and physical. Many of its assertions around integration offer space for the introduction of science and space education in the primary school setting. The curriculum emphasises the importance of connecting learning in different subjects giving the child, a broad and rich perspective and the interconnectedness of ideas (NCCA, 1999). It clearly states that "a rich experience of different aspects of the curriculum outside the classroom adds enormously to the relevance and effectiveness of the child's learning" (NCCA, 1999, p. 15).

2.2. STEM outreach for primary schools

Teaching children creative problem-solving skills from a young age will future benefit many STEM fields by developing a strong science, mathematics, and technology base from the beginning of a child's education (Petre and Price, 2004; Rogers and Portsmore, 2004; Selwyn, 2015; Jorgenson and Vu, 2016).

The primary school science curriculum is critical as it "cultivates a positive attitude to science and provides pupils with opportunities to experience the excitement of working as a scientist" (DES, 2008, p. iii). This inspectorate report (DES, 2008) on the science curriculum in Irish primary schools recommended to give children more opportunities for open-ended investigations. A key aim of Spaceship Earth was to instil in young children an excitement for atmospheric science and in turn encourage them to explore other STEM disciplines. Two of the four concept strands in primary science are *Energy and forces* and *Environmental awareness and care* and are addressed in the Spaceship Earth project (DES, 2008). Many of the procedural understanding concepts expected to be learned in primary school are also concentrated upon in our mission such as questioning, observing, predicting, investigating, experimenting, estimating, measuring and analysing (DES, 2008). A main comment of the Department of Education inspectors' study was on the over use of textbooks and not enough practical activity-based learning (DES, 2008), both of which were addressed as part of the Spaceship Earth project through the use of the weather balloon and experiment design.

For primary school level, some science fairs and competitions are seen as intimidating due to their length and complexity. Suggestions given by Schmidt and Kelter (2017) in making these outreach events more age appropriate would be to assist shorter and smaller projects, allowing children work in larger groups. High Altitude Balloon Projects allow children to work in large groups and create reasonably attainable projects which can be completed in short steps that keep the children engaged.

3. Theoretical framework

Jean Piaget's (1898–1980) (Constable, 2014, p. 10) influence is visible in STEM school philosophy with echoes of 'active learners' and 'taking information in through their experiences in their own world'. His focus on 'the material, physical world of the senses and active movement' (Bruce, 2011, p. 10) can be recognised too within the principles of forest schools. Likewise, Steiner (1864-1925) (Edmunds, 1987) strove to develop the link he had observed between children and the natural world. Steiner provided learning environments and natural materials that encouraged creativity and free thinking. From the progression education movement, John Dewey (1859–1952) (Rivkin 1998, p. 199), similarly advocated the use of the outdoors as an essential component of a child's education and valued it immensely in the education of children. Rivkin (1998, p. 200) envisions the school stepping in to provide an adapted version of the 'ideal home,' Dewey's antidote to an industrialised world, where the learning is led by the child's needs, provides opportunities to interact with one another and the environment.

Though the powerful value of the outdoors and nature has been recognised for many centuries, the educational discipline of outdoor education research has only recently developed as the complex nature of student learning and teacher practices evolved. The Swiss philosopher Rousseau longed for a society unshackled by restrictions and spoke out against urbanisation and civilisation as the cause of our alienation from nature and from feeling (Gupta, 2005). Rousseau asserted that we should follow the desires of childhood 'indulge its sports, its pleasures, its delightful instincts' (cited in Rusk and Scotland, 1985, p.180). He claimed that between the ages of 2 and 12 years, as the child's intuitive reasoning is directly linked to body movement and the senses, we should allow nature to take its own course (Crain, 2015). Echoed by Pestalozzi later, Rousseau believed that allowing the child's nature to lead did not equate to leaving the child to their own devices, in fact, he warned explicitly against this (cited in Rusk and Scotland, 1985).

In order to design and implement a series of 'spaceship' sessions in a primary school setting, we must explore its impact from the child's perspective. When designing the research, the following eight salient values, emerging from the literature review, were considered as central to implementing the Spaceship Earth project within the primary school context for effective learning (Table 1). Each element of the outreach project aimed to incorporate these sensitivities.

4. Research method

As research has evolved from researching 'on' children to 'for' and 'with' them (Fargas-Malet et al., 2010), it was decided to invite the primary school fourth class pupils to participate. The methodology employed in this study echoes the work of Scaife and Rogers (1999) who advocate involving school pupils in the design process as they have motivational information and insights adults do not. This understanding, of action research with an interpretative research paradigm, helps identify it as the methodology of choice for this exploratory study of the potential of space and science within the primary school context.

TABLE 1 Literature supporting SpaceShip Earth design.

Sensitivity	Main authors cited in literature
Incorporate reflection to inform future sessions	Froebel (Lilley, 1967)
Connect the child to natural world	Steiner (Edmunds, 1987), Dewey (Dewey, 1997; Rivkin, 1998), Malaguzzi (Constable, 2014), Pestalozzi (Rusk and Scotland, 1985), Sobel (2005)
Centre around the learner	Piaget (Constable, 2014), Rousseau (Rusk and Scotland, 1985)
As a skilled practitioner, provide an enriched environment	Roe et al. (2013), Farah et al. (2008)
Incorporate adventure through uncertainty and supported risk	Dewey (Dewey, 1997; Rivkin, 1998), Beames and Brown (2016)
Develop a space for creativity and agency	Steiner (Edmunds, 1987), Malaguzzi (Constable, 2014)
Incorporate authentic challenge to achieve flow	Csikszentmihalyi and LeFerve (1989), Beames and Brown (2016)
Integrate curriculum subjects	DES (1999), NCCA (1999), Bacon (2018)

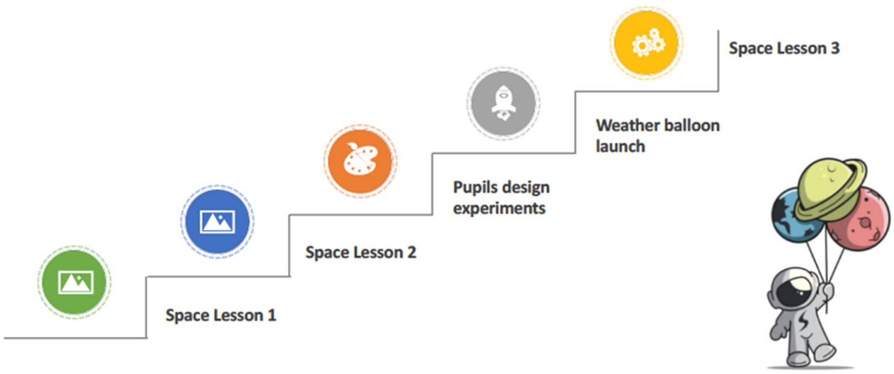

FIGURE 1
Roadmap for Spaceship Earth.

4.1. Participants

For a study to be action research there must be a 'collaborative development of ideas, processes, designs, actions, and reflective evaluation on the success or failure of these actions' (Greenwood, 2015, p. 204). Throughout the intervention and during the three Space Lessons (Figure 1) teachers and students were reflecting on their experiences, deepening their understanding and interpreting meaning for themselves.

Aiming for the highest level of good quality participation possible within action research, Pant (2014) recognises the role of action research in the redistribution of power, away from the professional researchers, the 'knowledge elite' (p. 291), toward those directly experiencing the situation being studied. Considering this, the school pupils, teachers, and school leaders were invited to participate in the study.

The United Nations Conventions on the Rights of the Child (Children's Rights Alliance, 2010) as well as Irish National Strategy on Child and Young People's Participation in Decision Making 2015–2020 (Department of Children and Youth Affairs, 2015) promotes involving children's view in matters that affect them. Therefore, this study employs a participatory methodology where the pupils are one of the key stakeholders in the action research process described in the next section.

4.2. Data collection and analytical approach

Guided by Kitchen and Steven (2008) the research methodology focused on measuring changes in children's attitudes toward STEM.

A pre-validated survey designed to measure children's attitudes toward STEM (Faber et al., 2013) was administered. All participants completed the same questionnaire at two different stages of the project (pre- and post-launch of the high-altitude weather balloons). The questionnaire took approximately 20 min to complete each time. The collection of data from the participants was conducted by an existing classroom teacher (and not one of the researchers, so as to not influence the participants while they are completing the questionnaires).

Final data was analysed using SPSS. Descriptive statistics was generated from both versions of the questionnaire. A participant identifier will be recorded as well as their answers from the 'before' survey and 'after' survey. Results will be compared to see if there was a statistically significant difference in their attitudes toward STEM after participating in the project. Depending on whether the data is parametric or not, paired t-tests or Wilcoxon's test was used to identify any differences. Correlations within the data was also examined for any existing associations within the data.

Teachers views on the project were also gathered through interviews as they were asked their opinion, feedback and suggestions regarding the project, implementation and integration in classroom lessons. The study was approved by the Faculty of Education and Health Sciences Research Ethics Committee at the participant University (EHSREC approval number: 2020_02_04_EHS).

5. Designing an integrated outreach STEM project

Supportive outreach is critical to the implementation of policy, enabling teachers to keep abreast of advancements in best practices. Taking the work by Kelley and Knowles (2016) as the foundational framework (see Figure 2), the design of the Spaceship Earth programme (see Figure 3), was formed by taking their five components as central to the integrated STEM outreach education programme.

The Spaceship Earth project was funded by Science Foundation Ireland (SFI) in collaboration with Universities and Met Eireann (Irish Meteorological Society) with an overall aim designed to inspire, encourage and engage the general public, teachers, and especially young children to learn more about STEM. Interacting in real world problem-solving experiments an overarching ambition of the project was to expose the primary school pupils to the possibilities of pursuing a STEM based career in their future. Taking the Kelley and Knowles framework which was developed for secondary and high school education, our adaptation, see Figure 3, was designed for primary school outreach activity, with Spaceship Earth as the case in point. The 12-month project was administered over the academic year, the duration of each component integrated throughout the Spaceship Earth project.

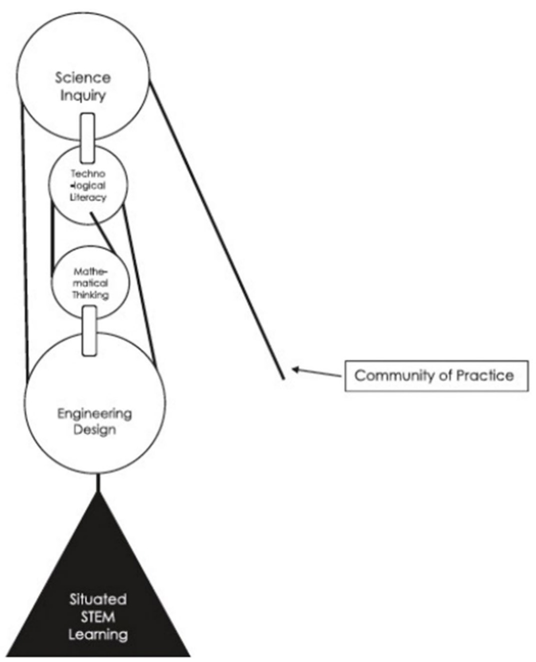

FIGURE 2
Integrated STEM outreach (reproduced from Kelley and Knowles, 2016, licensed under CC BY 4.0).

The delivery of Spaceship Earth occurred during the COVID-19 pandemic when access to schools was severely restricted. Consequently two Space Lessons were conducted online by the university experts, with over 300 primary school pupils attending in three different locations nationally. The learning intention of Space Lesson 1 was to introduce STEM and 'space' to the pupils. The learning intention of Space Lesson 2 was to debate with the pupils the idea of weather and discuss the role that high-altitude balloons play in helping us predict the weather. We then briefly outlined some experiment ideas that other children have previously sent up to the edge of space. With the assistance of their teachers, supported by the research team, the pupils designed the experiments to send to the edge of space. The launch of the weather balloons happened at the Met Eireann Observatory with some of the pupils and their parents attending. When the payloads were sourced after their flights, the experiments were returned to the schools and a follow-up 'Space Lesson 3' delivered (see Figure 1), meeting with the pupils to talk to them about the success of the project and to outline some of the preliminary results.

The framework for Spaceship Earth, an integrated STEM outreach project, had four pillars as depicted in Figure 3 and are each described in the following sections.

5.1. Situated STEM learning

The integration of high-altitude balloon practical experiments in the primary school curriculum can provide an effective method of involving pupils in a space-related mission. According to the basic constructivist theory, pupils learn most when they are given the opportunity to explore and create knowledge that is of personal interest to them (Papert, 1993). It is agreed that constructivism is a valuable perspective because once students are engaged in what they are doing, they are more motivated to learn. The approach can be particularly valuable to pupils who may have found the traditional instruction-based settings and subjects challenging. The constructivist method of teaching allows a learner build their knowledge (construct) as a result of experiences and reflection. Lectures and textbooks have only a passive role – the process of learning is very much a personal one. It follows that each learner's view is personal and, as such, is unique to each learner. A teacher's task in a constructivist setting is to facilitate the learner's building of this view. This view of the teaching process is similar to Laurillard's model of teaching as conversation or by participation in debate (Laurillard, 2013). Constructivism suggests that learners construct their own understanding, key principles of which involve situated learning, social knowledge, and collaboration. As with any theory, constructivism does not provide a complete picture of learning. Attention, perception, metacognition, and the limitations of working memory all influence learning, as does modelling and judiciously applied reinforcers. These concepts come from information processing, social cognitive theory, and behaviourism. Effective educators and educational programmes draw from such theories to promote as much learning as possible.

An example of the impact of the Spaceship Earth programme demonstrated that the pupils were able to recall key information from a presentation delivered during the project, including scientific facts, to younger students a whole year later with no revision done on the project. The excitement of practical hands-on learning had a strong influence on the pupils peaking their interest in STEM and encouraging them to retain the information they had learned (Kansaku et al., 2007).

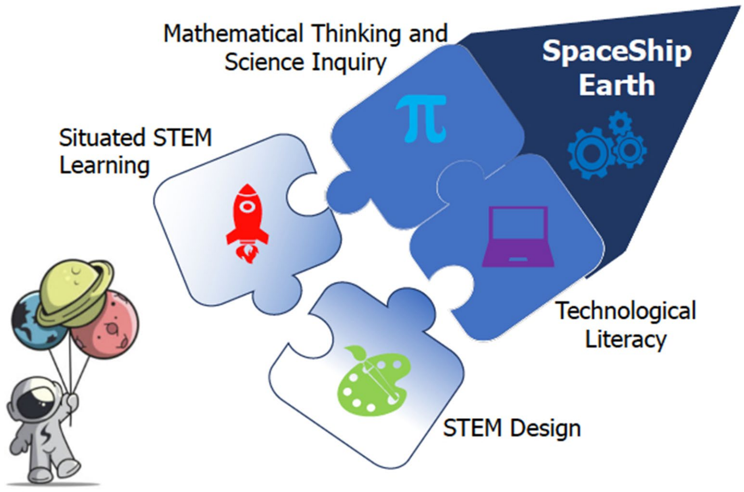

FIGURE 3
Integrated STEM outreach for Spaceship Earth.

5.2. STEM design

Three high-altitude balloons, containing small but numerous educational projects chosen by the pupils, were realised to the edge of space to help teach them about the conditions in space. In terms of engineering the STEM design the four elements (science, technology, engineering and mathematics) were integral to the experiments offered and chosen. The pupils were exposed to all four STEM elements in offering a range of experiments to choose from Table 2.

As the maximum payload in each balloon was 1,500 g, with 500 g allocated for electronics (e.g., gps/data logger), the remaining 1,000 g was allocated for the experiments which consisted of roughly 20 experiments each weighing 50 g. In total three balloons, containing small but educational projects chosen by the students to teach them about the conditions that can be found in space, were prepared for launch. One larger weather balloon was then utilised to attempt to break the world record for the highest Paper Aircraft launch. In the first two online lessons the Spaceship Earth team held paper plane making activities to engage the children in the design process of the larger plane to be launched.

Once the balloons has reached the edge of space and returned to Earth the experiments were returned to the schools and the students were able to compare the experiments exposed to near space conditions with their original ground level form, analysing and discussing differences.

5.3. Technological literacy

Based on the work of Kelley and Knowles (2016, p. 6) "technology consists of a body of knowledge, skills, and practices." The COVID-19 pandemic arose in the middle of this research study. Therefore the format of Spaceship Earth and engaging the pupils in real-world project-based experiments in the classroom had to be redesigned. The pandemic has shed much light on the challenges within our education system, and due to the COVID-19 pandemic the interaction and presentation of the Space Lessons were conducted online.

Online environments can exhibit technological affordances and features that more effectively support collaborative learning (Garrison et al., 2003; Roberts and McInnerney, 2007; Woo and Reeves, 2007). The use of digital technologies in these environments enable active online dialogue and collaboration, both synchronously and asynchronously (Romiszowski and Mason et al., 1996; Gunawardena and McIsaac, 2004) and adapting these technologies provides for student collaboration in a more participatory culture (Herrington et al., 2014). Also it is evidenced that collaborative group work can be enabled through the use of online tools allowing pupils to share knowledge through authentic, communal tasks, thereby building interdependence and shared learning.

In this project, the high-altitude balloons, which start out measuring about 1.8 metres (6 feet) in diameter before release, expand in the high altitudes due to the reduced air pressure to be about 7 or 8 metres (23–26 feet) in diameter. Filled with helium, the balloon has a lower density than air which then generates the lift. The balloon expands until it bursts and drops the payload. The experiments are returned to Earth via a parachute deploying as pressure increases on the descent to ground level, allowing the experiment to glide safely at approximately 5 m/s to landing. Attached to the payload were GPS trackers using the surrounding satellites to send signals to a mobile app (STRATOfinder[1]) to give a 5 m radius location of the payload's landing. A HDaction camera (similar to a GoPro) was also used to gather breath-taking footage of the flight capturing the Earth's blue hemisphere contrasting against the darkness of space in the stratosphere.

5.4. Mathematical thinking and science inquiry

Mathematical thinking is vital because it equips students with the ability to use mathematics. NRICH (2019) states that "exploring, questioning, working systematically, visualising, conjecturing, explaining, generalising, justifying, proving… are all at the heart of

1 https://www.stratoflights.com/en/shop/gps-tracker-stratofinder/

TABLE 2 STEM activities embedding in SpaceShip Earth.

S	Science	Experiments sent to space, example: - Sunflower Seeds and comparing the growth of sunflower seeds exposed to space conditions – with regular sunflower seeds on the Earth's surface. - Low pressure causes objects to expand in space. Sending a marshmallow to space will it get bigger after being exposed to the reduced pressure in space? - Low pressure causes liquids to boil and this is why astronauts wear protective gear so that their bodily fluids do not boil. If we send a wet sponge in the weather balloon what will happen? - Rubber band test to investigate what happen to its elasticity. Space conditions should cause the rubber band to lose some of its ability to return to its original shape. - A food test, demonstrating the cold temperature in space, certain foods would freeze in the middle if sent to space.
T	Technology	Using GPS trackers, data loggers, online learning, zoom meetings – all of evidence of the Technology utilised.
E	Engineering	Paper plane making activities to engage the class in the design process of the larger plane to be launched
M	Mathematics	Interpreting experiment data after and from the data loggers. Examining the graphs of the flight of the balloons and drawing correct conclusions from them.

mathematical thinking." Supported by an atmosphere of questioning, challenging, and reflecting and importantly mathematical thinking and science inquiry helps in understanding yourself and the world (Stacey et al., 1982; Schmidt and Kelter, 2017). It was our intention to develop the students' mathematical thinking and scientific inquiry provoked by contradiction, tension, and surprise.

Infant classes, namely junior and senior infants (pupils aged 5 and 6 years old) focus on basic scientific skills developments such as questioning, observing, predicting/estimating, investigating, measuring and analysing while experimenting (DES, 2008). The pupils begin their science education looking at basic topics like living things and properties of materials such as plastic and metal etc. Furthermore pupils continue to develop their scientific skills and branch out to slightly tougher subjects like environmental awareness and care in the curriculum. In most Irish primary schools it is in 2nd / 3rd class (ages 7 and 8 years old) when the first mention of space and its conditions come into the classroom as pupils begin to explore the topic of energy and forces such as light, sound, and heat. This was the deciding factor for our class group selections for the Spaceship Earth workshops and we invited the 4th class groups (age 9 or 10 years old) to participate. It is also at this stage where the school pupils have a higher ability to evaluate projects and experiments from their previous explorations and investigations.

6. Conclusion

The Spaceship Earth project provided primary schools with an innovative opportunity to engage in an integrated curriculum project that the research team designed with the assistance of teachers and students to develop a deeper understanding of STEM disciplines, while also allowing students to see STEM as an interconnected entity with a strong connection to the real world.

The project had profound success in the schools involved in the exploratory cycle. Data gathered resulted in a positive attitudinal change for the children who participated in each of categories of the Faber et al. (2013) survey administered. The survey included descriptions of subject areas that involve math, science, engineering and/or technology, and listed jobs connected to each subject area. Gathering this data of the children who participated in the SpaceShip Earth not only informs the project team and education designers but can influence STEM educational policy.

During Space Lesson 3 in particular the project team met with the pupils and teachers to talk to them about the success of the project and outline some of the preliminary payload experiment results with the children. The reflective discussion with the teachers exemplified the value in the importance of purpose and empirical relevance to practitioners in conceptualising and enacting educational design (McKenney and Schunn, 2018) and also in supporting them to conduct and participate in research (Teaching Council, 2021).

In supporting the students to send experiments to the 'edge of space' the project team designed an integrated STEM outreach project developing students' learning, rather than a project rather than purely riding on the coattails of society's interest in all things STEM (English, 2017). The integrated approach to STEM is important in inter- and transdisciplinary knowledge acquisition, as often the STEM acronym masks projects which are mainly scientific or engineering projects (English, 2017). The Spaceship Earth project undoubtedly succeeded in achieving this 'integrated' approach by interweaving the four pillars of STEM together throughout the project and by embedding opportunities for students to engage with each pillar across the entire project.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving human participants were reviewed and approved by the Faculty of Education and Health Sciences Research

Ethics Committee (EHSREC approval number: 2020_02_04_EHS). Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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