ATS STEM

Assessment of Transversal Skills in STEM

National Report for Ireland on Field Trials of Assessment of Transversal Skills in STEM

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Contents

CHAPTER 1. INTRODUCTION

The purpose of this report is twofold: to document the implementation of the ATS STEM programme in Ireland and to relay the findings from the analysis of the qualitative data collected. This report is organised as follows: Chapter 1 provides information on the Irish educational system and the participating schools in this study. Details of the STEM projects are also presented. Chapter 2 is concerned with methodology. Information on the data collected and analysed from the two case studies schools is discussed. Chapter 3 provides the results. Detailed information on the digital tools used is first presented, followed by the results, which are organised around the six dimensions associated with formative assessment achievements; "Integrate STEM content", "Reflect STEM learning design principles", "Facilitate feedback", "Facilitate peer-assessment", "Facilitate self-assessment", and "Help to Elicit evidence of learning". Finally, Chapter 4 documents the conclusion of the data analysis and offers recommendations and proposals for future implementation of STEM and digital assessment projects in schools.

1.1. IRISH EDUCATIONAL SYSTEM

In Ireland, education is compulsory from six to sixteen (or three years of second level). This is depicted in Figure 1-1 by the red line. However, in practice, 40% of Irish children start school at 4, with 99% of all children in school at age 5, and 90% of students complete the full five/six-year second level educational cycle (European Commission, 2017).

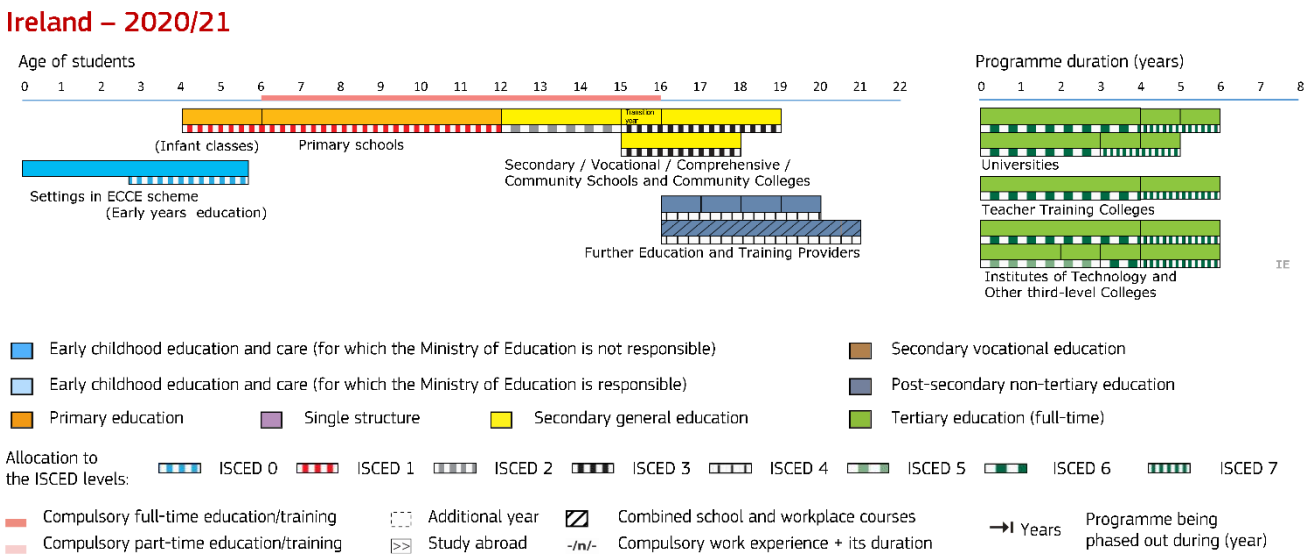


Figure 1-1 The Structure of the Irish Educational System (reproduced with permission) (Baïdak, Sicurella and Matti Riiheläinen, 2020)

The Department of Education and Skills is a department of the Government of Ireland led by the Minister for Education. This Department is responsible for the funding, regulation, policy, and provision of the educational system in Ireland. Governmental educational support extends from free Early Childhood Care and Education (age 3 and 2 months) to third level (University, Institutes of Technology, Further Education Colleges), where the government pays the third-level tuition fees. However, students have to pay a registration fee.

Primary Education

Most primary schools in Ireland are state-funded, consisting of parish (religious) schools, non-denominational schools, multi-denominational schools and gaelscoileanna (Irish language schools). The primary educational cycle is eight years, consisting of the following classes: junior infants, senior infants, and first to sixth class. At age twelve, students transfer to second level schools. The key components of the primary curriculum are illustrated in Figure 1-2. The following subject areas are covered: Mathematics, Languages, Arts Education, Social, Environment and Scientific Education, Physical Education, Social, Personal and Health Education and Religious Education.

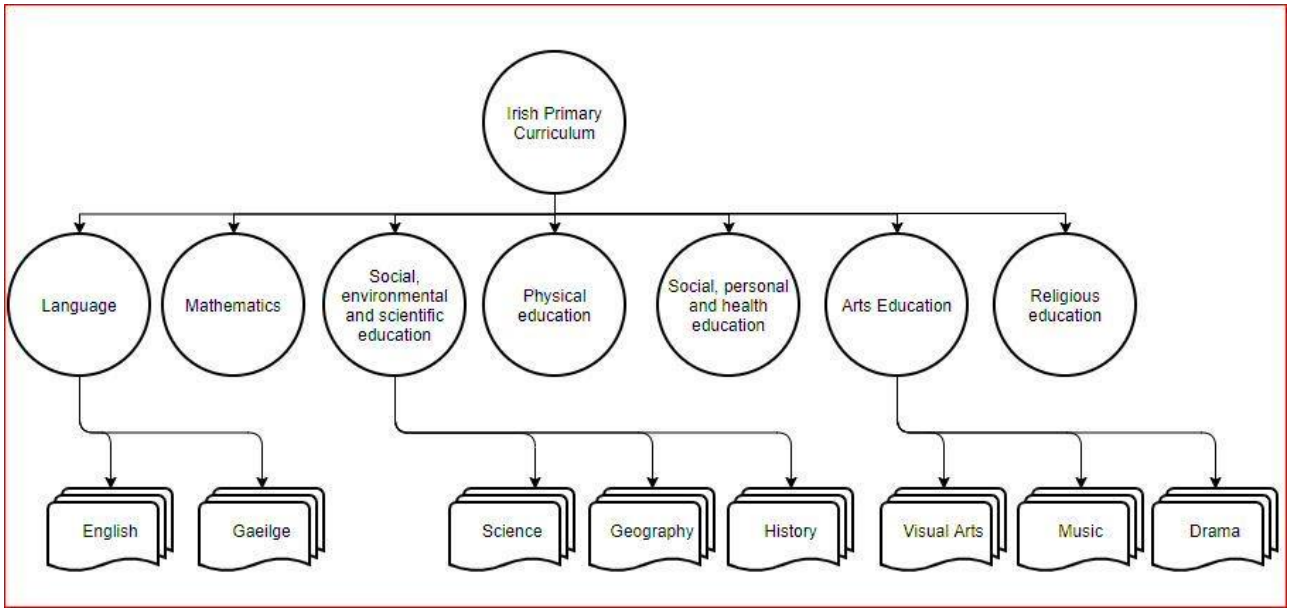


Figure 1-2 Irish Primary Curriculum (Based on image by Government of Ireland, 1999)

Second Level Education

Second level education starts for most Irish students at age twelve. It consists of a three-year Junior Cycle (lower secondary), followed by an optional Transitions Year (TY) and a two/three-year Senior Cycle (upper secondary).

The three-year Junior Cycle ends with a Junior Cycle Programme of Achievement. Typically, a student takes nine subjects and two short courses with English, Mathematics, Irish, and History (from 2020) being compulsory. The curriculum consists of a mix of subjects and short courses. However, not all subjects are offered in every school. The subject choices include: Applied Technology, Business Studies, Classics, Engineering, English, Environmental Social Studies, Irish, Geography, Graphics, History, Home Economics, Jewish Studies, Mathematics, Modern Foreign Languages, Music, Religious Education, Science, Visual Art. The following choice of short courses exist: Coding, Civic, Social and Political Education (CSPE), Physical Education (PE), Digital Media Literacy (DML), A Personal Project: Caring for Animals (Level 2), Social, Personal and Health Education (SPHE), Artistic Performance, CSI: Exploring Forensic Science (Level 2), Chinese Language and Culture and Philosophy.

Transition year follows the Junior Cycle. This year is optional, and it provides students with a wide range of educational subjects and inputs, including work experience, charity, and community work. This year is free from formal assessments and exams.

The Senior Cycle follows either Transition year or the Junior Cycle. It is a two-year programme, and at the end students take one of three State Exams: (traditional) Leaving Certificate, Leaving Certificate Vocational Programme or the Leaving Certificate Applied. The majority of students take the traditional Leaving Certificate Exam, where they have a choice of

thirty-six subjects and are required to take at least five, with Irish being compulsory. Most students take seven, as their best six grades (achieved in one sitting) are used to calculate points for entry to third-level colleges. Mathematics and English are a requirement for most third-level colleges. The subjects available to study for the standard Leaving Certificate include: Languages group: English, French, German, Irish, Italian, Latin, Greek, Spanish, Arabic, Japanese, Russian, Classical Studies, Hebrew Studies: Science Group: Applied Mathematics, Biology, Chemistry, Mathematics, Physics, Physics and Chemistry: Business studies group: Accounting, Business, Economics: Applied science group: Agricultural Science, Construction Studies, Engineering, Home Economics, Physics and Chemistry, Design and Communication Graphics, Technology, Computer Science, Physical Education: Social studies group: Art, Geography, History, Home Economics, Music, Politics and Society, Religious Education. (NCCA, no date).

1.1.2. STEM EDUCATION IN THE NATIONAL EDUCATION SYSTEM

The ATS STEM Work Package 1 deliverables namely ATS STEM Reports 'STEM Education in Schools: What Can We Learn from the Research?' and 'Government Responses to the Challenge of STEM Education: Case Studies from Europe', delve into the Irish and European STEM education and policy landscape. The reports note that Ireland defines STEM education as multi-faceted and one that goes beyond the main disciplines that constitute the acronym STEM. The foundation for STEM education, according to the Irish STEM framework, is built in early childhood. Children develop curiosity, inquisitiveness, critical-thinking and problem-solving capacities which are built on STEM exploration and creativity through their primary and post-primary school experience.

The four STEM constituent disciplines in Ireland were reported as Science, Technology, Engineering and Mathematics. Within these four STEM disciplines, there are a wide range of STEM subjects that learners can engage in during their school life. These can range from designing and craft in primary school to Science, Technology, Engineering, and Mathematics at post-primary level. There is no definitive list of STEM subjects and recent consultations with teachers, parents, and learners found considerable variance of views in this regard. According to ATS STEM Report #2, 'Government Responses to the Challenge of STEM Education: Case Studies from Europe', in Ireland the policy advocates that STEM education not only involves the teaching of disciplines and subjects in isolation, but it also involves a cross-disciplinary approach.

In ATS STEM Report #2 lists Ireland's 'STEM Education in the Irish School System Report' which was developed by the STEM Education Review Group and published in November 2016. The STEM education policy in Ireland was developed by employing various methods: consideration for national and international research in the area of concern, the extensive consultation process with over 600 responses on public consultation and stakeholder consultation with 80 attendees. Consultations with learners, parents, and teachers - primary and post-primary - were also crucial in forming the policy along with Early Years Inspectorate and Early Years Unit. The STEM Education Consultation Report 2017 was published as a result of this process. The development of the policy was overseen by a STEM Education Steering group. In Ireland, the Policy Statement advocates for increased uptake of STEM learners of all backgrounds, ability, and gender.

1.1.3. DIGITAL ASSESSMENT IN THE NATIONAL EDUCATION SYSTEM

Within the project outputs, the ATS STEM Report #3 'Digital Formative Assessment of Transversal Skills In STEM' aims to promote awareness towards the need for digital formative assessment plans to cohere with other Irish educational priorities and ensure equity in access to digital tools and programmes. Further awareness initiatives are needed for policy makers and other stakeholders to gain an understanding of the key questions and considerations surrounding digital assessment in Ireland. Teachers and teacher educators especially need to be supported in the design, implementation and potential use of digital assessment tools and practices. The need for investment and cooperation in further research and development for digital assessment is highlighted in both local and Pan-European contexts.

Ireland has been a part of experimental projects surrounding digital assessment like the Assessment of Transversal Skills 2020 (ATS2020), a large scale European funded research study involving 250 schools, 10,000 students (10-15 years old) and 1000 teachers from 10 countries. The project was designed principally to investigate the impact of innovative teaching and learning approaches allied to the use of ePortfolios and electronic journaling on the development of transversal skills across four competence areas: Information Literacy, Autonomous Learning, Collaboration and Communication, and Creativity and Innovation (see, http://www.ats2020.eu/). It was noted that "implementing an innovative learning model and its critical elements, such as ePortfolio, assessment of, for and as learning, development of transversal skills, and technology-enhanced learning design, is a complex process for both teachers and students, and it needs time to be adopted" (Economou, 2018, p. 28).

1.2. CONTEXT OF THE PILOT SCHOOLS

In Ireland, recruitment of pilot and case study schools was delayed due to COVID-19. Thirteen schools took part in the study; eleven pilot schools and two case study schools. Four of the eleven pilot schools dropped out. The remaining seven consisted of three primary schools and four second level schools. Full details of the pilot schools are described in table 1-1, with information on the case study schools described in section 1.3.

Table1-1 Irish Pilot School Information

School Identifier	Type	Level	Class Group	Teacher No.	Student No.	No. LCs	Teacher Subjects	No. Projects Implemented
School 1	Primary, co-educational, Catholic Ethos, semi-urban	6th Class	1	1 (Female)	28	2	all subjects	Pollution of the River Nile: LC 1 (Clean Water and Sanitation) LC2 (Building a Shaduf)
School 4	Primary, gaelscoil	5th Class	1	1 (Male)	27	1	all subjects	Creating a modern Green School Plan
School 5	Primary, multi-denominational schools, public	5th Class	2	2 (Male)	42	1	all subjects	<school town> New Facilities
School 2	Secondary, Post-primary, all boys day and boarding school	1st Year	1	1 (Female)	26	0	Science and Maths Teacher	Project (water pollution) but not completed. Had initial difficulties with consent forms
School 8	Secondary, post-primary Catholic co-educational day school	2nd Years	2	1 (Male)	40	1	Science Teacher	Investigating wind power

School 9	Post-primary, Community School, co-educational school, operates under the joint trusteeship of the <county> Education and Training Board , the Presentation Sisters and the Archbishop of Dublin.	1st Year	2	1 (female)	32	1	Science Teacher	Clean & Sustainable Energy
School 11	Secondary, Post-primary, urban area It is a large co-educational school	1st, 2nd and 5th Years	4	5 (female)	96		Digital Media Literacy Computer Science Business, LCVP	None due to COVID

1.3. DESCRIPTION OF CASE STUDY SCHOOLS

Two case study schools were selected for this study: a primary level, and a second level school. Details of the schools are provided in the following section.

Case study 1

Case study 1 is a co-educational public Catholic primary school. The school currently has 177 pupils enrolled from ages 4 to 12 years. The school staff comprises thirteen teachers along with support staff; 1 principal teacher, 7 mainstream class teachers, three and a half Learning Support Teachers, two ASD (Autistic Spectrum Disorder) Class Teachers, and eight Special Needs Assistants. The students live in a mostly rural/semi-urban defined catchment area. The subjects covered are Gaeilge (Irish) and English, Mathematics, Social, Environmental and Scientific Education: History, Geography, Science, Art Education, Music; Visual Arts, and Drama; and Social Personal and Health Education. The school's mission statement is to ensure all students feel welcome and safe, that they respect each other, learn, and are happy at school. The pupils and parents/guardians of the 6th class together with their teacher (Teacher 1), consented to be a case study school.

Case study 2

Case study 2 is a co-educational public post-primary interdenominational school. It caters for 553 pupils from ages 12 to 18 years, and has 61 teachers, 53 female and 8 male. The students live in a primarily rural and coastal geographically defined catchment area. It is a DEIS school, which stands for Delivering Equality of Opportunity in School. This is a Department of Education and Skills educational inclusion programme that caters for the educational needs of students from disadvantaged communities. The school provides a broad range of curricular programmes including: the Junior Cycle programme, Junior Certificate School Programme, optional Transition Year (TY) programme, Leaving Certificate Vocational Programme, Leaving Certificate Applied, and the established Leaving Certificate. The school's mission is concerned with promoting an atmosphere of respect, honesty, and fairness. This school had four teachers participating in the study, all science teachers, 1 male, and three females. The male teacher (Teacher 2) who taught 2nd Year Science consented (with his students and their parents) to participate in the case study

1.3.2. DETAILED DESCRIPTION OF THE STEM PROJECTS DEVELOPED DURING THE PILOT

This section provides detailed information on the ATS STEM projects conducted by the case study schools, in both learning cycles. Information provided for both schools includes project implementation details, learning intentions, competences, success criteria, digital assessment strategies and digital tools. The learning cycles are discussed in sequential order per school.

LEARNING CYCLE 1: CASE STUDY SCHOOL 1

Case Study School 1 completed two learning cycles. The first learning cycle was concerned with students designing a 2D Sensory Garden and an arch. A Sensory Garden was planned to be designed and built in the school during the summer of 2021. This task allowed students to contribute their ideas before the landscape designer and builder implemented the project.

Before the start of Learning Cycle 1, the participant teacher filled out six ATS STEM learning design cards. These cards were designed by members of the DCU Research team in partnership with the lead mentor in Kildare Education Centre. They are directly derived from the ATS STEM conceptual framework and its consistent elements but draw more broadly on visual learning design methods particularly for allowing teachers to talk about learning design. These cards identify the core steps previously outlined as important when designing a STEM task. Figure 1-3 shows cards titled 'Real-World Contexts' as a learning design principle and starting card ("Setting the Context") that a teachers has completed.

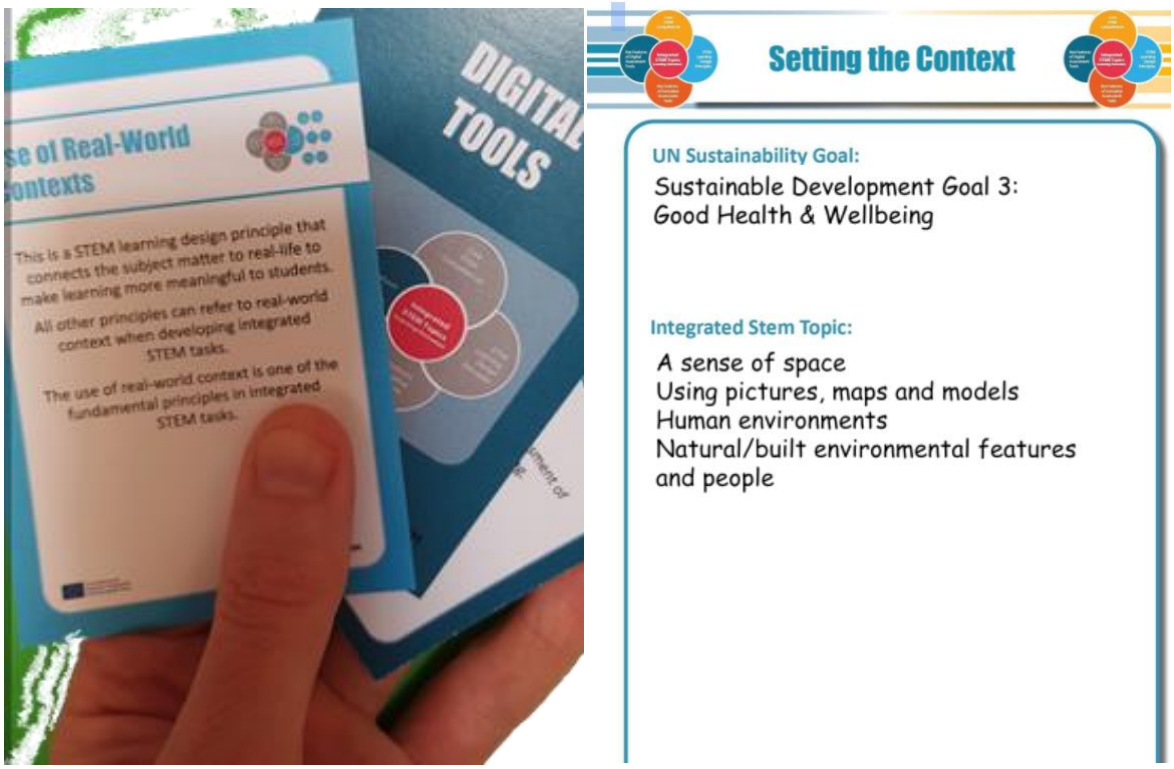


Figure 1-3 STEM Learning Design Cards, Setting the Context card filled out by Teacher 1

The six ATS STEM learning design cards capture the following information: Setting the Context, Core STEM competences, Learning Outcomes and Success Criteria, STEM Learning Design Principles, Digital Formative Assessment and STEM Task Details. Project information and details from these cards are described in the next section.

Figure1-4 Proposed location of where Sensory Garden is to be located on School Premises

Project Information Summary for Learning Cycle 1, School 1: 25th January to 18th March 2021

Table 1-1 Summary information for STEM Project Learning Cycle 1, School 1

Project	**Designing a 2D Sensory Garden**
Duration of the lesson	*Two online lessons 30 minutes each plus home instructions (this occurred during lockdown)* *Two class lessons (1.5 hours) each*
Number and year level of students	*19 students from 6th Class*
Teachers responsible	*1 Primary School Teacher*

Subjects/topics involved	*Mathematics, Science, Art, and History*
Total amount of lessons during the implementation	*4 lessons*
Artefacts produced during the implementation	*2D design plans of the garden, plans of an arch for the garden, Self-assessment of the design, mentimeter answers to design questions*

Learning Intentions and competences

The context for designing a 2D garden was the UN Sustainable Development Goal 3: Good Health and Wellbeing. This goal integrated the following STEM topics: 'A sense of space', 'Using pictures, maps and models', 'Human environments' and 'Natural/built environmental features and people'. The task of designing the sensory garden focused on two core STEM competences: Problem-solving and Innovation and Creativity. The elements of problem-solving that the students engaged with were gathering information, decision making, and finding solutions.

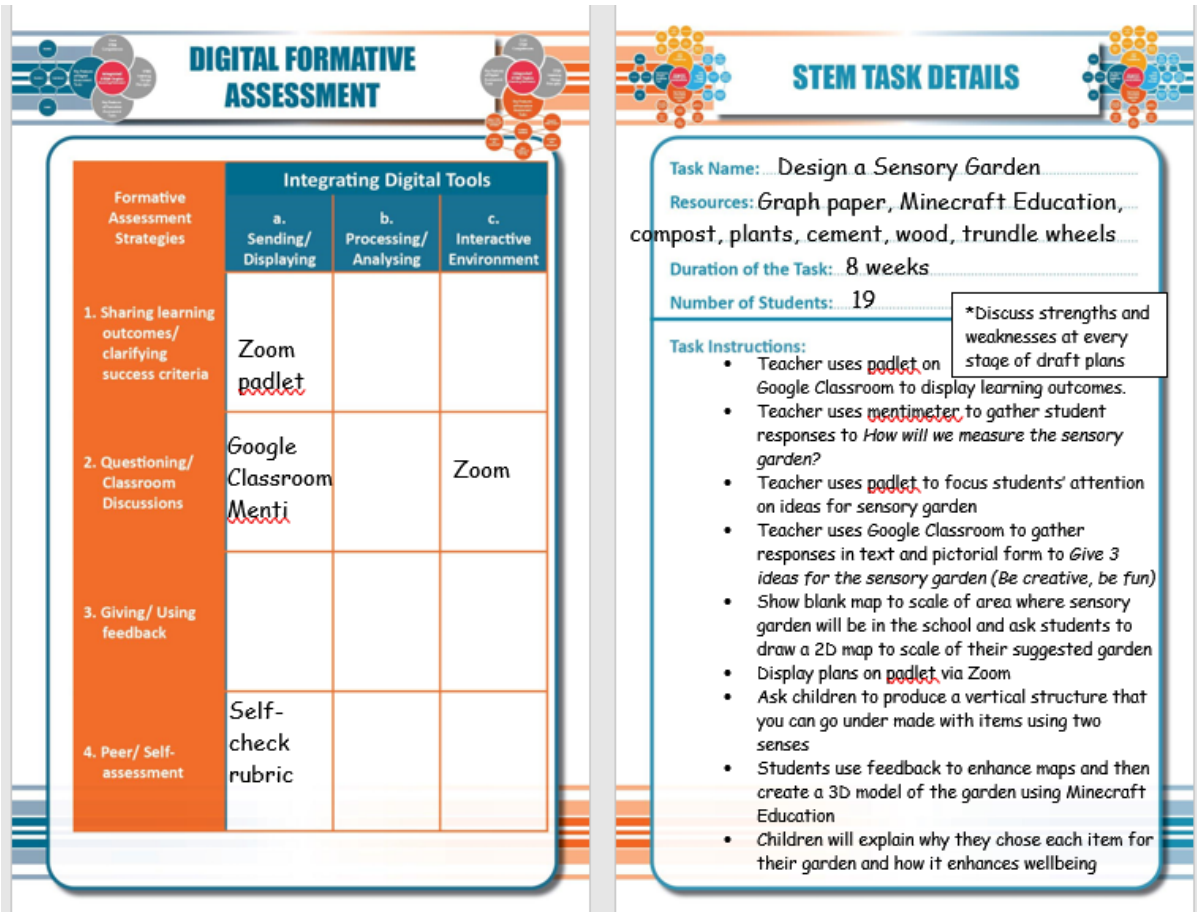


Figure 1-5 displays the four different digital tools used during LC1: ZOOM, Padlet, Google Classroom and Mentimeter. Details of the same can be found in Table 1-2. The STEM Task Details Card is also illustrated. Both cards were filled out by Teacher 1.

The elements of innovation and creativity that they engaged in were using their imagination, coming up with new ideas, and physically creating something original. The learning outcomes and success criteria were defined as follows:

Learning Outcomes

By the end of activity students will be able to:

- Research ideas for a sensory garden
- Measure the area of the garden
- Design a 2D map of the garden

Success Criteria

The success criteria were identified as students being able to:

- Identify at least three items for the sensory garden
- Produce a 2D draft plan to scale with the location of sensory items labelled.

The digital tools and assessment strategies used in this project are summarised in Figure 1-5 with Table 1-2 providing a more detailed description of each tool.

Table 1-2 Digital Tools used by School 1 in LC1

Name	Description	Source
Padlet	Online notice board tool. It was used by the teacher during online classes to 1) display learning outcomes, 2) focus students' attention on ideas for the sensory garden 3) display student designs during class. As lockdown progressed, students became more familiar with using Padlet, and it became a favourite of all.	https://padlet.com/
Mentimeter	Interactive presentation Tool. Used by the teacher to ascertain student responses to the question: How will we measure the sensory garden? This tool was used during lockdown. The teacher first visited the school by herself during lockdown and created a video of her on the proposed site for the sensory garden. She then posed the question “What will I use to measure the garden space?”. Using Mentimeter, students answered it in their own	https://www.mentimeter.com/

	time, as not all students attended the online daily ZOOM classes.	
Google Classroom	During Lockdown, Google classroom was used (asynchronously) to gather responses in both text and pictorial format from students regarding their ideas for the sensory garden and the design for their arches. It was also used in ZOOM classes. The teacher was also able to put voice notes in the classroom.	https://edu.google.com/intl/en/products/classroom/
Zoom	ZOOM is a video conferencing platform. During Lockdown Zoom was used by the teacher to conduct online classes.	https://zoom.us/

Comments

With reference to the original learning outcomes, Teacher 1 had also planned for students to create 3D plans of the sensory garden using Minecraft. This learning outcome was put on hold due to COVID-19 lockdown. It was hoped to be incorporated into Learning Cycle 2 when schools reopened, but due to software difficulties, the plan could not proceed. Also, the goal for Learning Cycle 2 became more "outdoor" focused, ensuring students spent more time outdoors during their school day. During the implementation of Learning Cycle 1, Teacher 1 found that she needed to give students more specific elements in the design, so she added a task “design an arch for the garden” to the activity.

LEARNING CYCLE 2: CASE STUDY SCHOOL 1

Learning Cycle 2 was concerned with students identifying Native Irish Trees and creating an eBook of the same (see Figure 1-7). The identification process focused explicitly on bud identification as the activity took place in Spring 2021 when not many trees had leaves. The context for this STEM task was the UN Sustainable Development Goal 15: Life on Land. Similar to Learning Cycle 1, the participant teacher filled out the aforementioned six ATS STEM learning design cards. Figure 1-6 depicts the first card 'Setting the Context'.

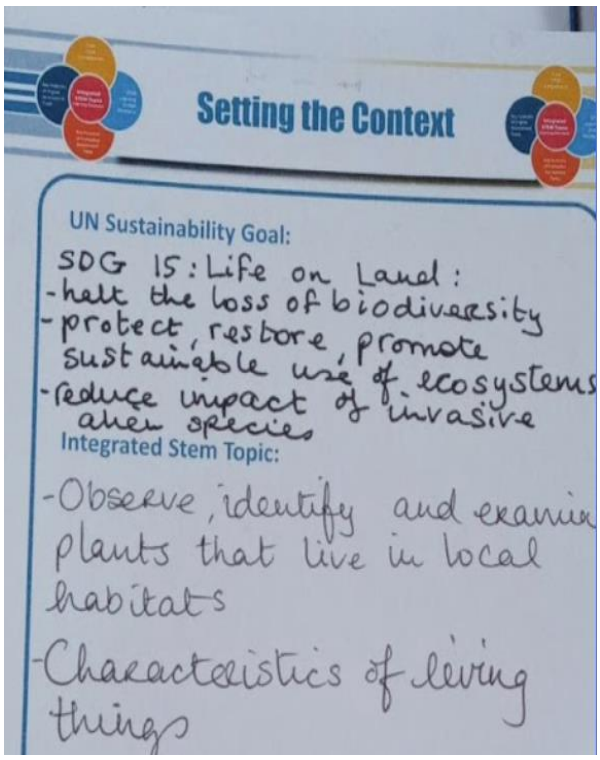


Figure 1-6 Setting the Context ATS STEM Card. Figure 1-7 Photo of students drawing sketches of Irish Native Tree buds located on school grounds. These sketches will be incorporated into their ebooks.

The 'Life on Land' goal integrated the following STEM topics: 'Observe, identify and examine plants that live in local habitats and to investigate the 'Characteristics of Living Things'. The task of identifying native Irish trees focused on three core STEM competences; Problem-solving, Collaboration, and Disciplinary competences. The elements of problem-solving that the students engaged with were gathering information, asking questions, and making decisions. The elements of collaboration concerned students working together to effectively communicate with each other, and to take turns with the use of the iPads. This competence was particularly relevant, as students were just back into school after a three-month lockdown, and as part of COVID restrictions, students were placed in class bubbles and pods. The last competence concerned students' use of technology, specifically the iPad. Project information is summarised in the Table 1-3, and described in detail in the next section.

Project Information Summary for Learning Cycle 2: 25th March to 26th April 2021

Table 1-3 Project Information for Learning Cycle 2, School 1

Project	**Identifying Native Irish Trees and creating an eBook based on the identification.**
Duration of the lesson	*Four class lessons. three lessons were 1.5hrs and one lesson was 30 minutes*
Number and year level of students	*19 students from 6th Class*
Teachers responsible	*1 Primary School Teacher*
Subjects/topics involved	*Science, Art, and History*
Total amount of lessons during the implementation	*4 lessons*
Artefacts produced during the implementation	*eBook on Native Trees, Self-assessment rubric for collaboration, Mentimeter answers to native tree questions, blooket quiz, teacher slides*

Learning Intentions and Competences:

The Learning Outcomes were defined as follows:

- Make a tree identification guide
- Use iPad/laptop to gather information
- Identify native Irish trees around the school
- Work with others and take turns

The Success Criteria were defined as follows:

- Children will gather information, ask questions and make decisions as part of a group
- Children will use computers effectively to take photos and add to Padlet/Adobe webpage/Book Creator

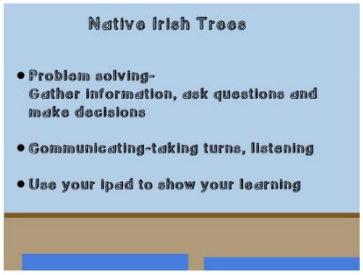
The digital tools and assessment strategies used in this project are summarised in Table 1-4, with Table 1-5 providing a more detailed description of the tools.

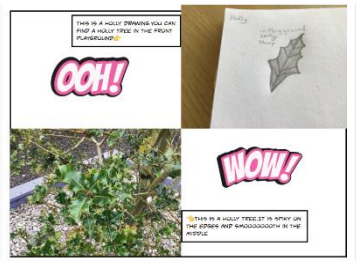
Table 1-4 Digital tools and assessment strategies

	Sending and/or Displaying	**Analysing and/or Processing**	**Interactive environment**
-Sharing learning intentions **- Clarifying success criteria**	ActivInspire Whiteboard,		
- Questioning **- Classroom discussions**	Mentimeter and IWB, Blooket	Blooket	
- Giving feedback **- Using feedback**	Blooket		
- Self-assessment **- Peer assessment**	Book Creator, (paper-based peer assessment form)		

Table 1-5 provides a description of the tools used, accompanied with an image depicting its use.

Table 1-5 Digital Tools used by School 1 (LC2)

Name	Description	Image	Source
Interactive White Board	The interactive whiteboard was used to facilitate the displaying of slides that displayed to students the core STEM competences for the lesson		

Mentimeter	Interactive presentation Tool. This tool was used to pose questions to the students to ascertain current knowledge before the topics were discussed in class. Questions asked to students were: Name three things we use trees for? What other creatures use trees?	 	https://www.mentimeter.com/
BookCreator	Digital tool used to create books online. This tool allows the teacher to create a digital library where all students can store their books. Thus facilitating the teacher to show 'work in progress' from each group to the class and enabling teacher and peer feedback.		https://bookcreator.com/
Blooket	Blooket is a web-based quiz game platform. The participant teacher used it to ascertain students' pre and post-lesson knowledge of native Irish trees.		https://www.blooket.com/

CASE STUDY SCHOOL 2

Case Study School 2 also completed two learning cycles. This section provides information on the implemented STEM projects, learning intentions, competences, success criteria, digital assessment strategies and digital tools for School 2.

LEARNING CYCLE 1: CASE STUDY SCHOOL 2

Learning Cycle 1 was concerned with energy. The students were assigned two tasks (see Table 1-6), which they did alongside their Junior Cycle Science CBA (Continuous Based Assessment). Project information is summarised in Table 1-7.

Table 1-6 provides details of the tasks required by students for Learning Cycle 1

Task Details	**Digital Tool Tasks**
Students should be able to research different energy sources; formulate and communicate an informed view of ways that current and future energy needs on Earth can be met. Q. The local council has asked you to research three different sources of energy that could help power the town.	Research online with your device and compare different ways we can compare current and future energy needs on various sources
Students should be able to research and discuss the ethical and sustainability issues that arise from our generation and consumption of electricity. Q. You have been asked by the Sustainable Energy Authority of Ireland (SEAI) to research different ethical (right and wrong issues) and sustainability (long-lasting) issues of energy consumption by Irish households.	Using your device, in teams, look and discuss the different long-term issues from our current electricity use.

Project Information Summary for Learning Cycle 1: 11th January to19th February 2021

Table 1-7 provides a summary of the main components of the Project, such as durations, lessons, subjects covered etc.

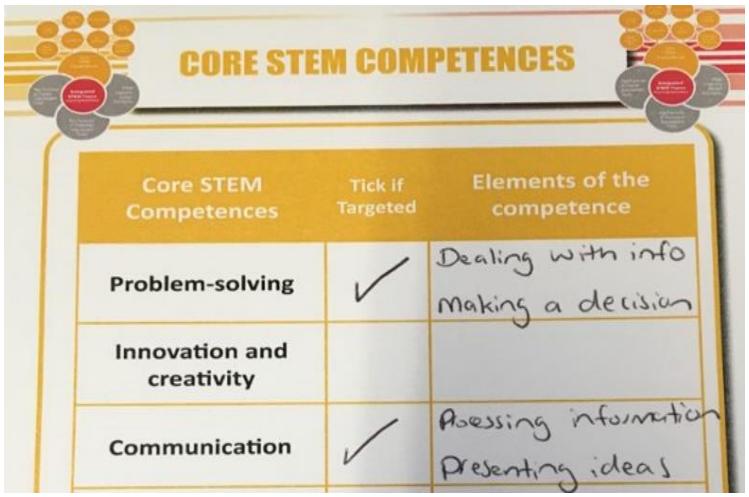
Table 1-7 Project Information for School 2 (LC1)

Project	**Energy: Ethical and sustainability issues**
Duration of the lesson	*1 hour*
Number and year level of students	*22 students from 2nd Year*
Teachers responsible	*1 Science Teacher*
Subjects/topics involved	*Science, Geography, CSPE*
Total amount of lessons during the implementation	*3 hrs. a week, teacher taught "even" classes, the other classes students worked on their own.* *Six weeks, 18 lessons (however students worked on their CBAs during this time as well)*
Artefacts produced during the implementation	*Student slides or word document, photographs, mentimeter answers to energy questions*

Learning Intentions and competences:

The above tasks (see Table 1-6) were completed by students during lockdown at their homes, but during "school hours". The context for the STEM project was the UN Sustainable Development Goal 7: Clean and Affordable Energy. This goal was also relevant to the Irish Educational Junior Cycle Continuous Based Assessment (CBA) as one of the themes for this assessment was energy. Task 1 and 2 were relevant to content on the Junior Cycle Science course, specifically regarding Earth and Space. Students researched and discussed the ethical and sustainability issues that arise from the generation

and consumption of electricity. As before the participant teacher filled out the ATS STEM learning design cards (Figure 1-8). The tasks focused on two core STEM competences; Problem-solving and Communication.



CORE STEM COMPETENCES

Core STEM Competences	Tick if Targeted	Elements of the competence
Problem-solving	✓	Dealing with info making a decision
Innovation and creativity		
Communication	✓	Processing information Presenting ideas

Figure 1-8 STEM competences; Problem-solving and Communication

Students were tasked with researching and answering the following two questions:

- The local council has asked you to research three different sources of energy that could help power the town.
- You have been asked by the Sustainable Energy Authority of Ireland (SEAI) to research different ethical (right and wrong issues) and sustainability (long-lasting) issues of energy consumption by Irish households.

The Learning Outcomes and Success criteria are defined in Figure 1-9 and also as follows:

<u>Learning Outcomes</u>

By the end of the tasks, students will be able to:

- Critically evaluate issues with generation and use of energy for the home
- Suggest sustainable ways to deal with energy consumption

<u>Success Criteria</u>

The success criteria are based on:

- Defining ethical issues in terms of current use of electricity with examples
- Suggesting sustainable ways Ireland can be more efficient in electricity generation and consumption
- Providing a diagram for each ethical and sustainable issue with website reference links

Learning Outcomes & Success Criteria

- **Identify the learning outcomes in a way that makes learning visible:** Students to evaluate critically the issues with our current generation and use of energy for the home. Students should suggest more sustainable ways to overcome such issues for the future.

- **Define success criteria in a way that makes success visible:** For explanation of ethical and sustainable issues of generation and use of electricity give 5 examples for each, include:

1. Define ethical issues in terms of current use of electricity, 5 examples
2. Suggest 5 sustainable ways Ireland can be more efficient with electricity generation & consumption
3. Diagram for each one (where possible) for ethical **AND** sustainable issues. Include any website links you used e.g. http://seai.ie at the end.

Figure 1-9 Learning Outcomes and Success Criteria

The digital tools and assessment strategies used in this project are summarised in Figure 1-10, with Table 1-8 providing a more detailed description of the tools. Note Figure 1-13 is a screenshot of the ATS STEM learning design card written by Teacher 2.

Digital tools

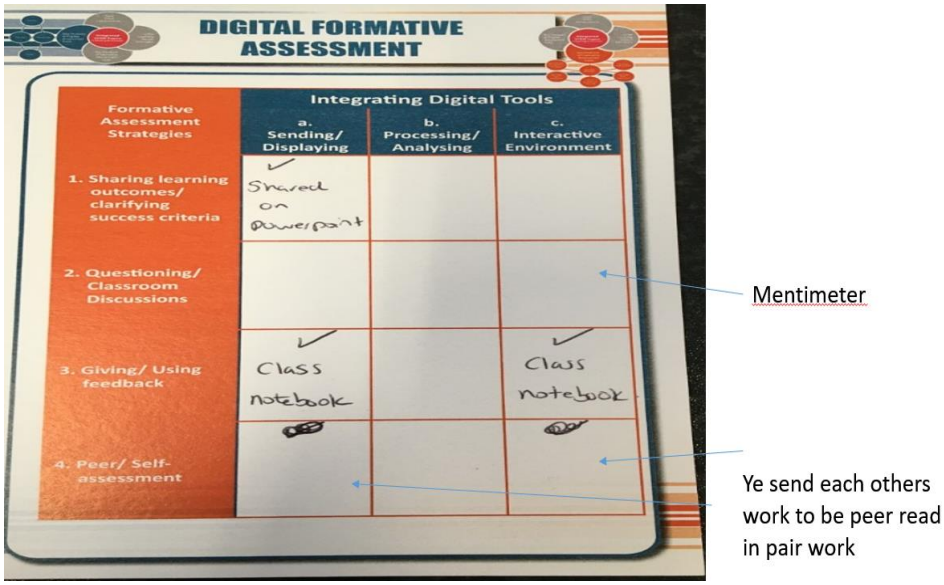


Figure 1-10 Digital Tool Use Plan

From Figure 1-10, one can see that three different digital tools were used, Mentimeter, MS Team's class notebook, and PowerPoint. Lessons were conducted online using Microsoft Teams and assessments were uploaded to same.

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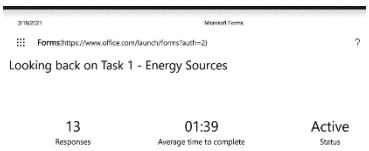
Table 1-8 Description of the tools used by Teacher 2 in Learning Cycle 1

Name	**Description**	**Image**	**Source**
MS Teams and Whiteboard	MS Teams is a hub for team collaboration, consisting of video, messaging and sharing resources online. Online Class were conducted using Teams. MS Teams has various elements of which a shared whiteboard is one which both students and teacher can write on.		
MS Teams Class and students Notebook	Student Notebooks are a private space on MS Teams. Only the teacher and student can access them. Class Notebook is a notebook which the whole class can access. It can store images, texts, videos, voice messages etc.		
MS Forms	Tool to easily create surveys, quizzes and polls. Used by the teacher to ascertain students' perspectives on digital tools and assessments used in his class.		https://forms.office.com/
Mentimeter	Interactive presentation Tool. Used by teacher to ask the following questions: What problems are there in Ireland with our current use of energy in the homes?		https://www.mentimeter.com/

LEARNING CYCLE 2: CASE STUDY SCHOOLS

Learning Cycle 2 was conducted from post-midterm to Easter holidays. It was concerned with Climate Change based on the UN Sustainable Goal 16: Climate Change. The context for this STEM task was Integrated Stem Topic: Learning Outcome: Earth & Space 7. Students were asked to illustrate how earth processes and human factors influence the Earth's climate and evaluate effects of climate change and initiatives that attempt to address those effects.

Task details: You are in a group of 3 scientists working for EPA Ireland. You are given 5 simple tasks to research, discuss and show by a simple experiment the phenomena of global warming or unnatural/natural global warming. Your group will be conducting a simple experiment at home, picturing it and videoing it as evidence showing the occurrence of global warming/climate change.

Project Information Summary for Learning Cycle 2:10th March to 18th March 2021

Table 1-9 provides a summary of the main components of the Project, such as durations, lessons, subjects covered etc.

Table 1-9 ATS STEM project details for School 2 Learning Cycle 2

Project	**Climate Change: Understanding effects of earth's processes and human interaction on climate change**
Duration of the lesson	*5 weeks for 3 hours per week*
Number and year level of students	*22 students from 2nd Year*
Teachers responsible	*1 Science Teacher*
Subjects/topics involved	*Science, Geography,*
Total amount of lessons during the implementation	*Five lessons*
Artefacts produced during the implementation	*Student slides or word document, photographs, Mentimeter answers to energy questions*

Learning Intentions and competences:

The tasks detailed above were completed by students during lockdown. Teaching occurred online during lockdown but the specific tasks were completed by individual students at their homes, but during "school hours". The context for the STEM project was 'UN Sustainable Development Goal 13 Climate Action: Take urgent action to combat climate change and its impacts' (Fig. 1-11) was also relevant to the Irish Educational Junior Cycle Continuous Based Assessment (CBA) as one of the themes for this assessment was energy.

Figure 1-11 Slide from Teacher's 2 Class Slides where he links the Students' project task to the UN Sustainable Goal of Climate Change

The context of the STEM project describes how this is an integrated STEM topic. Figure 1-12 depicts a student experiment developed during this Learning Cycle. This experiment representing the effect of greenhouse gases in trapping heat in the atmosphere. The following section is concerned with the learning outcomes and success criteria for the project.

Figure 1-12 Student Experiment developed during Learning Cycle 2 to show the effects of climate change and global warming.

Learning outcomes (Figure 1-13)

By the end of the task, students will be able to:

- Critically evaluate issues surrounding human interaction and Earth's processes that affect climate change
- Suggest initiatives and/or interventions to overcome such issues in current and future contexts

Success Criteria

The success criteria (Fig. 1-13) was based on students' ability to:

- Explain the difference between weather and climate
- List examples of Earth's process and human interaction that affect climate with diagrams
- Evaluate and explain how local community (County <School County>), Irish government, and United Nations Environmental Protection (UNEP) combat climate change
- Design and conduct a simple experiment to demonstrate how humans speed up climate change and global warming

Figure 1-13 displays a screenshot of the slide shown to the students which illustrate their learning outcomes and success criteria. Figure 1-14 captures the experiment undertaken by a student in School 2 showing the effects of rising sea water due to global warning on the ecosystem.

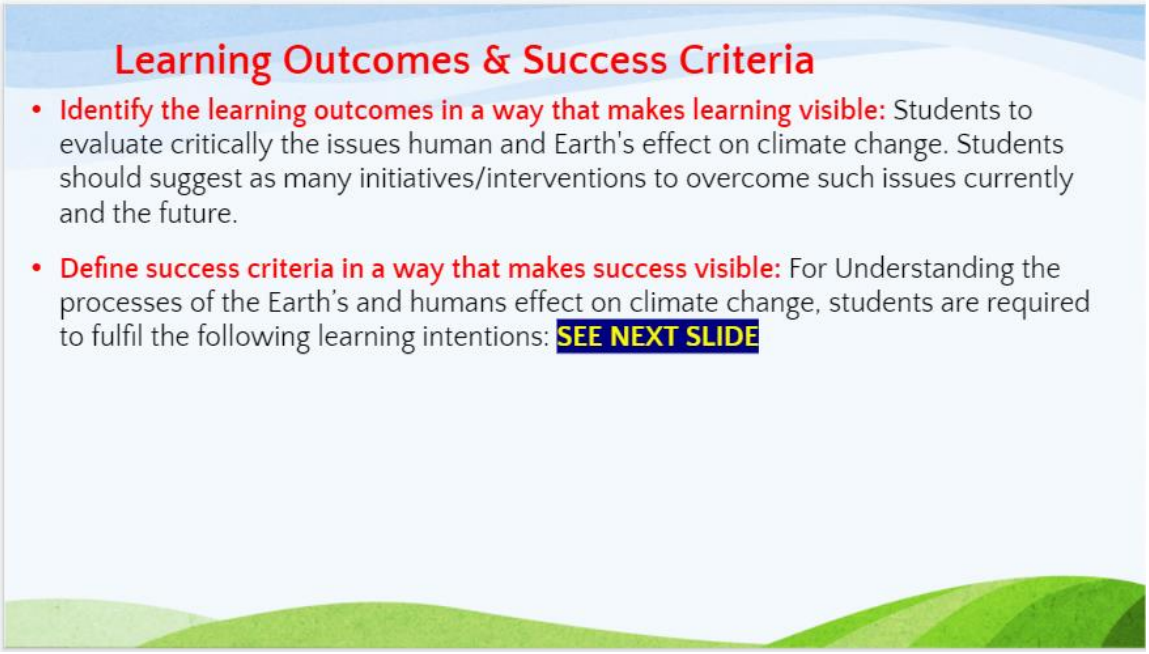
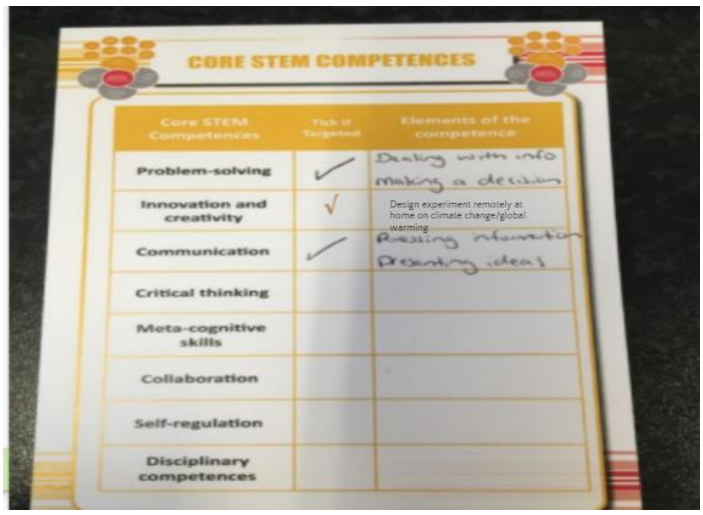


Figure 1-13 Learning Outcomes and Success Criteria for Learning Cycle 2 (School 2)

Figure 1-14 Student Experiment showing the effects of rising sea levels on the ecosystem.

As before the participant teacher filled out the ATS STEM learning design cards. The ATS STEM project was concerned with three Core STEM competences, Problem-solving, Innovation and creativity, and Communication (Fig. 1-15). The elements of problem-solving that the students engaged with were gathering information, asking questions, and making decisions. Innovation and creativity were demonstrated by conducting a simple experiment in line with the topic. Communication was used to dictate and record a video of the experiment to be shared with the rest of the class.



CORE STEM COMPETENCES

Core STEM Competences	Tick if Targeted	Elements of the competence
Problem-solving	✓	Dealing with info making a decision
Innovation and creativity	√	Design experiment remotely at home on climate change/global warming
Communication	✓	Pressing information presenting ideas
Critical thinking		
Meta-cognitive skills		
Collaboration		
Self-regulation		
Disciplinary competences		

Figure 1-15: Core Stem Competences for Learning Cycle 2 (School 2)

Digital Tools

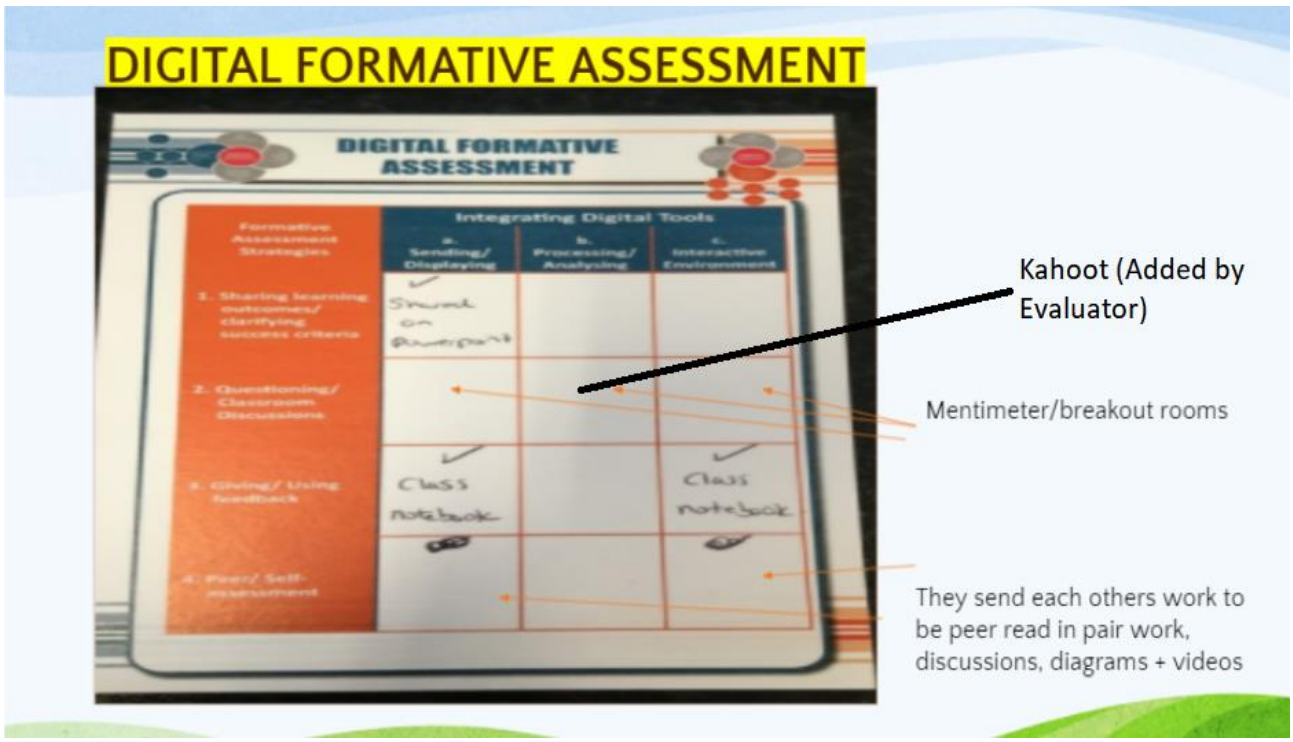
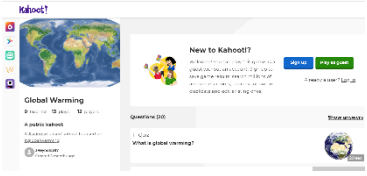


Figure 1-16 Formative Assessment Strategies and Digital Tools used During Learning Cycle 2.

Figure 1-16 depicts the formative assessment strategies and digital tools used during Learning Cycle 2. From Figure 1-16 one can see that three different digital tools were used (and written) by the Teacher 2: Mentimeter, MS Teams' class notebook, and PowerPoint. The teacher also used Kahoot, to assess knowledge after teaching. Lessons were conducted online using Microsoft Teams and assessments were uploaded to the same. Table 1-10 provides descriptions of all the digital tools used by Teacher 2 and his class.

Table 1-10 Description of Tools used by Teacher 2

Name	Description	Image	Source
MS Teams	MS Teams is a hub for team collaboration, consisting of video, messaging and sharing resources online. Online Class were conducted using Teams		
MS Teams Class and students Notebook	Student Notebooks are a private space shared in MS Teams. Only the teacher and respective student can access them. Class Notebook is a space/notebook which can be accessed by the whole class. It		

	can store images,texts, videos, voice messages etc.		
Mentimeter	Interactive presentation tool. Used by the teacher to ask questions after teaching a topic on climate change, for example: What are the problems linked to greenhouse gases such as methane and CO2?		https://www.mentimeter.com/
Kahoot	Used by the teacher to assess knowledge after the lesson.		https://kahoot.com/

Final Comments

The effect COVID-19 had on this project has to be acknowledged. All students' lessons occurred online, students did not have access to a Science Lab, although the experiments they devised in Learning Cycle 2, showed their creativity under such circumstances.

CHAPTER 2. METHODOLOGY

This report concerns the findings from qualitative data gathering during the piloting of the ATS STEM project in Ireland. This data was gathered using various means: teacher group interviews, student focus groups, mentor group interviews, class observations, and students' and teachers' artefacts. The ATS STEM project was piloted in Ireland, during a level 5 lockdown and, as such, was impacted by COVID-19 restrictions. The lockdown started on 30th December 2020. Schools did not reopen until March 1st 2021, on a phased basis. Primary schools fully opened on March 15th 2021, and the 2nd Years in secondary schools (case study class) did not return to schools until 12th April 2021.

For this reason, no observations were conducted during Learning Cycle 1. However, observations did occur during Learning Cycle 2 for the primary school case study, as the children were back in schools and the STEM project was an outdoor project. All elements of this project were observed.

Learning Cycle 1

Data was collected at a group interview of all participating teachers (pilot and case study). This interview captured information on teachers currently in the process of Learning Cycle 1 or who had not started due to COVID issues. At the end of Learning Cycle 1, student and teacher artefacts from both case study schools were collected, such as student projects, teacher lesson plans, assessments and slides. Teacher slides were also collected from two of the pilot schools. Table 2-1 provides a summary of the collected data.

Learning Cycle 2

Student and teacher artefacts from both case study schools were collected, such as student projects, teacher lesson plans, assessments and slides. Three school observations occurred in case study school 1, as the project was an "outside" project. (Teacher slides were also collected from one of the pilot schools)

Learning Cycle 1 and Learning Cycle 2

Student focus groups occurred after Learning Cycle 2 for the case study schools, but students answered questions related to both cycles. Nine students (2 focus groups) were interviewed at case study school 1 and six students at case study school 2. Four teachers were interviewed. This consisted of two group interviews. Interview 0ne: primary school teachers. It consisted of one pilot school teacher and one case study school. Interview Two: secondary school teachers: It consisted of one pilot school and one case study school. The teachers from the case study school discussed both their learning cycles. The teachers from the pilot schools had only completed one learning cycle, which they both discussed. Mentor Interviews: The three mentors were also interviewed in a group interview.

Table 2-1

	School 1		School 2	
	LC 1	LC2	LC1	LC 2
Observations	0	3	0	0
Student Artefacts	28	10	19	5

Teacher Artefacts	Lesson Plans and ATS STEM learning design cards	Lesson Plans and ATS STEM learning design cards	Lesson Plans and ATS STEM learning design cards	Lesson Plans and ATS STEM learning design cards
Interviews	1 Primary School Group teachers interview (2 teachers: 1 pilot (male teacher), 1 case school (female teacher).		1 Secondary School Group Teachers interview (2 teachers: 1 pilot (male teacher), 1 case school (male teacher))	
	2 Primary focus groups (9 students). Age 12, five male and four females. Thirteen students had parental consent to be interviewed. The case study teacher selected the nine students based on the range of their abilities and also on their willingness to be interviewed on that day.		1 Primary focus groups (6 students). Age 14. The case study teacher selected the six students (5 male, 1 female) based on the range of abilities.	
	Three mentors, all female. The ATS STEM facilitator, mentor for primary schools and the mentor for secondary schools			
Misc.	Artefacts also collected from two pilot schools (1 primary, 1 secondary)			

2.1.1. PROCESS FOLLOWED FOR DATA COLLECTION THROUGH THE INSTRUMENTS

The data collection process started with an electronic initial questionnaire being filled out by nine out of twelve piloting schools in Ireland by April 2021. A total of 154 student responses were gathered from the initial questionnaire. The final questionnaire on the other hand was filled out by eight piloting schools with a total 80 responses gathered by middle of June 2021. In the primary schools, the teachers had to explain the questions to the students when they were undertaking the survey but overall the questionnaire was able to gather useful quantitative data. All interviews were conducted using the provided ATS STEM interview instruments as the reference source. However, the wording was simplified for the student interviews, and we adapted the teacher interview to fewer questions. Ethical approval was sought and gained from the DCU Research Ethics Committee (rec no. DCU REC/2020/274).

The ATS STEM observation sheet was used to record the observations. The process was as follows, the evaluator recorded the class observations every 5 minutes and then subsequently filled out the class observation instrument after each observation. Figure 2-1 shows an excerpt from the observation instrument.

		reflected)	
a. b. c. d.	1 Explanation/presentation digital format Y 2 Explanation/oral presentation Y 3 Discussion of objectives 4 Other: _____ 5 Discussion of objectives 6 Agreement on achievement criteria 7 Register of agreements 8 Other: _____	a.1. B.5 B.6 C. 9	Note of a.1. At the start of class the overall goals were recapped and students answered questions related to the design and implementation of a sensory garden. The Sustainable Goal is Health and well-being and Life on Land. The teacher used a powerpoint slide for students to identify the sustainable goals (from a picture) they were doing in their project. Students discussed the uses of the sensory garden as a place for relaxation, well being and mental health. They also stated that their design had a celtic theme

Figure 2-1 Excerpt from the 1st observation at case study School 1

The ATS STEM artefacts analysis sheet was used to analyze the student artefacts.

2.1.2. INCIDENTS TO BE TAKEN INTO ACCOUNT IN DATA COLLECTION

As stated above, COVID-19 was the biggest challenge for the data collection, specifically in relation to the observations. The COVID-19 restrictions during lockdown, which started on 30th December 2020, hindered data collection. Schools did not reopen until March 1st 2021, on a phased basis. Primary schools fully opened on March 15th 2021, and the 2nd Years in secondary schools (case study class) did not return to schools until 12th April 2021. For this reason, no observations were conducted during Learning Cycle 1, but observations did occur during Learning Cycle 2 for the primary school case study. Additional interviews and artefacts were collected for analysis to ensure that all essential data was captured.

2.2. DATA ANALYSIS

Process

Interviews were professionally transcribed. The coding process was conducted using the NVivo software, and the coding strategy was both inductive and deductive. The six dimensions guided the coding process, whilst the coding process was inductive, the codes generated were very much related to the questions, and the subsequent six dimensions.

Quality

The validity and reliability of the data gathered was maintained through a rigorous approval process. The overall ethics approval from University of Santiago (dated 17th April 2020) was included in the internal application to DCU Research Ethics Committee (rec no. DCU REC/2020/274). The application was also supported by an approval process from the DCU Data Protection Unit. Thus, data gathering only commenced after all necessary ethical guidelines were followed.

The observations and interviews were carried out by a qualified and experienced national evaluator who was garda (police) vetted in advance. The stability of data was assured with the national evaluator being present and involved in all data gathering endeavours. All participants were informed about the ATS STEM project in detail before consenting to participate in the study and the participation was on a voluntary basis. The ATS STEM facilitator from Kildare Education Centre, Ireland recruited two teacher mentors to the programme. Teachers/school personnel signed up to be pilot and case study participants after webinars with facilitators and workshops with mentors involved in the project. As minors, the students involved were given a child consent form and the data collection process was explained in plain language beforehand. Parents/guardians of the students volunteering were provided with detailed consent forms. All artefacts gathered in the data collection process were provided by the teacher to the research team after ensuring parental/guardian approval. Anonymity of all participants was ensured by the research team when seeking consent.

As stated in the section above, coding of the data was done through NVivo software. The coding was both inductive and deductive. The coding process was validated by dual verification within the research team headed by the national evaluator. All required data gathering instruments were used as per recommendation by methodology provided by Work Package 5. Extraction of data was done by all sources recommended i.e., pre and post piloting survey, artefacts, observation where possible, interviews with all participant groups with additional interviews and artefacts in lieu of pandemic restrictions around observation.

CHAPTER 3. RESULTS

3.1. RESULTS DESCRIPTION

3.1.1. DIGITAL ASSESSMENT DESCRIPTION

3.1.1.1. What digital assessment tools have teachers and students used? And how have they been used? (proposal for use by teachers within the framework of STEM projects)

As stated previously, Ireland was under a level 5 lockdown during the piloting of this project. Schools were operating remotely and in phases. Teachers were adapting to teaching online with digital tools available and experimenting with tools that would not normally be required in face-to-face teaching. In some instances, students were also provided instructions on how to use certain digital tools in advance of an anticipated lockdown. Thus, many more digital tools and platforms were used to deliver and pilot the ATS STEM project than foreseen. It must be noted that the wide range of digital tools being applied in classrooms during the piloting was in part due to COVID-19 circumstances. It would be interesting to gather and compare data under normal classroom conditions. List of digital tools used by the case study schools involved in the project can be found in the table below (Table 3-1).

Table 3-1 List of Digital Tools used by Case Study Schools

School 1	**School 2**
Padlet	MS Teams
Mentimeter	MS Teams Student Notebook
Zoom	MS Forms
Google Classroom	Mentimeter
Blooket	Kahoot
PowerPoint	PowerPoint
Book Creator	

Details of the application and reception of individual digital tools used in schools is as follows:

Mentimeter: This is an interactive presentation tool. It was used by Teacher 1 and Teacher 2 in both case study schools to facilitate the formative assessment strategy of questioning/classroom discussion (see Figures 1-5 and Figures 1-13). It was used both asynchronously and synchronously. It allowed all students to participate and share their ideas. It was also used to elicit evidence of learning. Teacher 1 used it asynchronously during lockdown. This required students to research the answer and post their responses individually. It was subsequently used by Teacher 1 synchronously in the classroom where questions were posed to students to activate prior/current knowledge on the topics before they were discussed in class. The students answered the Mentimeter question in pairs. This tool allowed all students to participate in the discussion without fear, as their answers were anonymous. All ideas were shared. A primary student reported that:

> "It was cool to see everyone else's ideas like. Because say, I came up with like a flower stuff or whatever, I put that in and I'd see if there was any other cool ideas that you could do with that from other people that put into the Mentee. Discuss with other people." (Student: Case School 1)

Teacher 2 also used Mentimeter as a way to ascertain current knowledge on a topic. It was used synchronously in online classrooms. Secondary students reported that this was a great way to ascertain keywords for their subsequent research and for providing topics to discuss in their online breakout rooms.

> "We used Mentee quite a lot to get a keyword on a topic. So, if we were doing something, on like, energy conservation, we'd like, we put down three words that come to mind when you think of energy conservation. Yeah, and then everyone in the class can see that and use those words too." (Student: Case School 2)

Figure 3-1 Mentimeter example from School 2, Learning Cycle 2

Blooket: Blooket is a web-based quiz game platform. It was used by Teacher 1 in the classroom to ascertain students' pre and post-lesson knowledge of native Irish trees. The students were observed completing this quiz in the classroom in pairs using a shared iPad. Students reported that they found this activity great fun. The tool reports on how many correct or incorrect responses per question, and it also has a leaderboard. Students were observed being encouraged that they were not alone in getting an answer wrong.

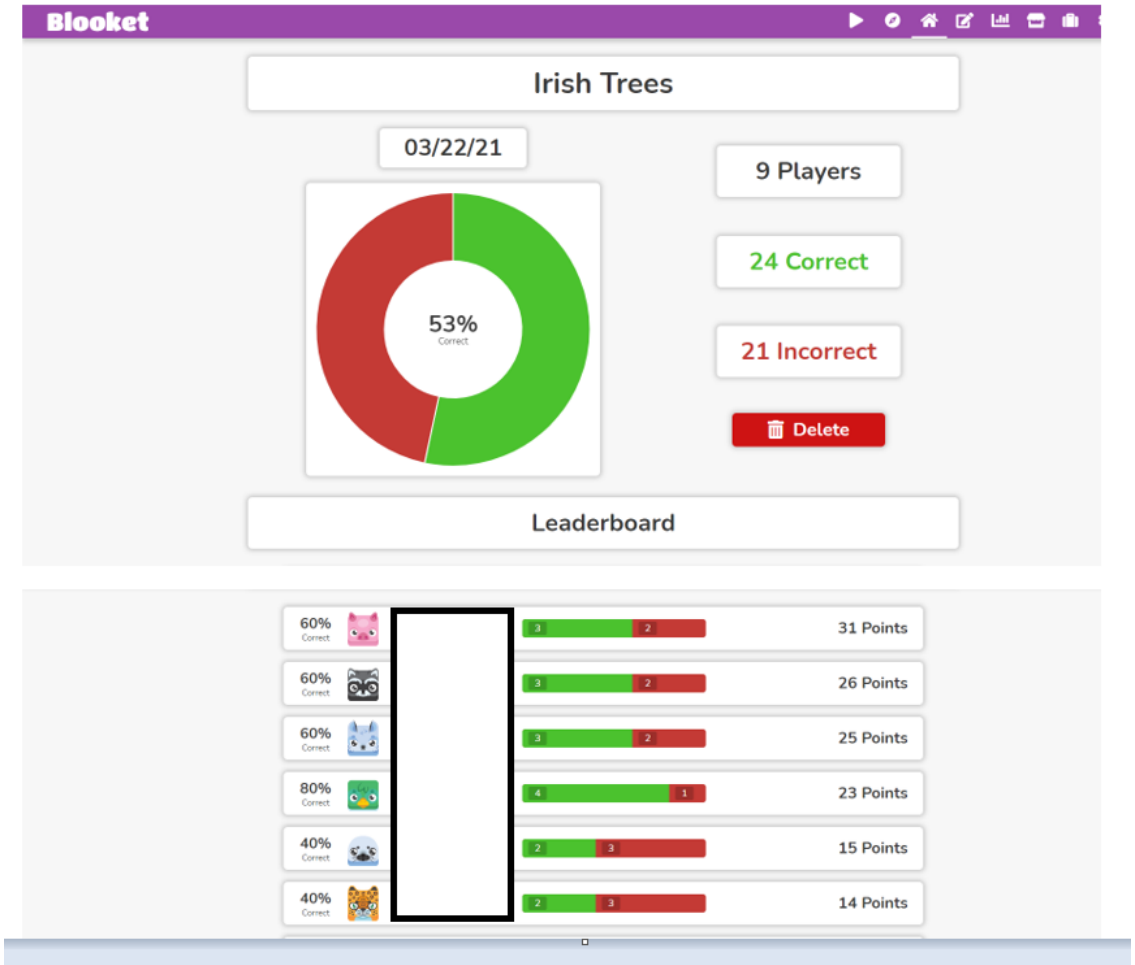


Figure 3-2 Blooket example from School 1 Learning Cycle 2

Students particularly enjoyed the competitive element of Blooket, where they were competing against other groups, in answering the questions correctly and quickly. Collaboration was encouraged. The teacher was observed stressing to students that both members had to agree with an answer before it was submitted. An unexpected finding was that students found that this tool helped with self-regulation. A sample of student responses include:

> "Blooket. That was my favourite."
>
> "Yeah, it was exciting even if you were at the bottom because then you were battling not to finish at the bottom a bit."
>
> "We kind of got to learn. Yeah, I learned all the trees off by heart then so I'd be quicker to do it."
>
> "Yeah, you would just memorise it."
>
> "Oh yeah, I kept on trying to get better. I don't think I ever won though."

Book Creator: This is a digital tool used to create books online. It was observed being used by Teacher 1 and her students. This tool was multifunctional in that it facilitated peer-assessment, discussion, creativity, problem solving and self-regulation. Students were tasked with consolidating their research and identification of native Irish trees into a book. The students in pairs designed a book for Junior infants (age 4-5 years). The purpose of the book was to show Junior Infants where the native Irish trees were located on the school grounds, and how you could identify them. Using iPads, the

students took pictures of trees on the school grounds. They also sketched the trees and their buds and took images of the same. The book creator tool allowed students to consolidate their images into a book. Students also added text where they described the trees and the location in the school grounds.

> **Student:** "Yeah, we did research on trees to get like, how like say, like you seeing I don't know, a birch tree; you'd look it up and you'd find like information and you'd like, write it down in your own words, if you get me."
>
> **Interviewer:** Okay, so when you're writing stuff about the tree you have to look up that information?
>
> **Student:** "Yeah, but write it in your own words and then you're not copyrighting."

The Book Creator app, allowed the teacher to show the students work in progress on her interactive white board. Students were observed getting excited seeing their work displayed. They discussed the "books in progress" and were inspired by other students' work: "So, I thought it was kind of cool to see it, and like other people's ideas on the on the Interactive Whiteboard because it was cool and I thought I was like, oh, I actually kind of really want." (Student Case Study 1). The students had full control over what native trees they selected for their content and their books' layout and style.

Padlet: This was used by Teacher 1 (LC1) during lockdown for students to upload their work. Students uploaded their finished work to Padlet and could also observe other students' work. The links for Padlet were located on the students' Google Classroom. Teacher 4 (Pilot school) also used Padlet. The teacher's usage facilitated peer assessment, where students upload their work to Padlet and other students were asked to comment on the same, where they posted one positive feedback and one element of advice. Teacher 4 also observed that his class saw another teacher's class Padlet with the same project work, so that became a source of inspiration and encouragement to his class.

PowerPoint: This tool was used by both Teacher 1 (LC2) and Teacher 2 (LC1, LC2) to share lesson outcomes and to clarify success criteria. Students also used it in School 2 to create, display and present their work, with several students mentioning how they liked that they learned how to use it. Students added photographs and videos to their presentations (Figure 3-3).

Figure 3-3 Student work using photograph (School 2, Learning Cycle 1)

Zoom: Zoom is a video conferencing platform. During Lockdown Zoom was used by Teacher 1 to conduct online classes. However, she was cognizant that not all students were able to log on, so zoom was used in conjunction with google classroom and Padlet.

Google Classroom: During Lockdown, Google classroom was used (asynchronously) to gather responses in both text and pictorial format from students regarding their ideas for the sensory garden and the design for their arches. It was also used in ZOOM classes. The teacher was also able to put voice notes in the classroom.

MS Teams: MS Teams is a hub for team collaboration, consisting of video, messaging and sharing resources online. Online Classes were conducted using MS Teams by Teacher 2. This tool facilitated collaboration, discussion and feedback. It provided breakout rooms which allowed students to collaborate and to discuss and share ideas. 'And also, when we were in the breakout rooms and if anyone had any good ideas, and I would be like, 'that's handy, going to use that one' (Student, Case Study School 2). MS Teams also facilitate feedback. Students used the assignment tab on the MS teams to upload their work in progress, and the teachers provided feedback on the same. "Assignments tab in teams and the teacher just sent in the feedback, and then we could just hand it in again with the changes." (Student Case Study School 2). "The feedback, I was giving feedback along the way, probably the two stars and a wish, the two good things about it and then obviously the one… how can you improve this the next task." (Teacher 2, School 2)

Kahoot: This is a game-based platform that allows the creation of online quizzes. This was used by Teacher 2 to elicit evidence of learning. It also provides feedback to students as the answers are given at the end.

> "Our kids like the Kahoot, so the Mentimeter is probably what I used before the prior, the building up work, and the Kahoot at the end for that kind of formative assessment of the questions. Because we would have done theory classes on it with the help of obviously CSPE and the geography classes with the materials that help as well. The Kahoot was like the assessment for it with that kind of fun interactive, because there's been so many classes researching, they want a bit of variety along the way to help them as well." (Teacher 2)

MS Forms: This was used by Teacher 2 to elicit feedback from the students on the assessment process. Teacher 2 created a survey to ask students what form of feedback they preferred, and to ascertain what digital tools they were using and if they helped with their projects.

3.1.2. FORMATIVE ASSESSMENT ACHIEVEMENTS

This section is concerned with findings related to formative assessment achievements. These achievements are described based on the six dimensions described in the ATS STEM Methodology. They are as follows:

1. Integrate STEM content (and learning outcomes/goals)

2. Reflect STEM learning design principles (and social constructivist views of learning)

3. Facilitate feedback (improve learning by prompting the learner to use effective feedback focused on the learning outcome/goal in a timely manner)

4. Facilitate peer-assessment (improve learning by activating students as instructional resources for one another)

5. Facilitate self-assessment (improve learning by activating students as owners of their own learning)

6. Help to Elicit evidence of learning (improve learning through questioning and discussion and by prompting activities that clarify the meaning of success)

Each of these dimensions is discussed in the following sections based on their subcategories and indicators described in the ATS STEM Methodology document.

3.1.2.1. INTEGRATE STEM CONTENT (AND LEARNING OUTCOMES/GOALS)

Learning objectives were presented, explained and discussed with students

School 1: Student and teacher discussion on the learning objectives were observed. Teacher 1 used PowerPoint to display the objectives and facilitate discussion. Their discussion on the sustainable goal of "Health and Well-being" and "Life on Land" linked to their design and implementation of a sensory garden. Mentimeter was used to discuss their understanding of the tasks. With reference to Learning Cycle 2, students discussed what the word "native" meant, why trees were important to the environment, and the importance of biodiversity regarding insects and pollination. At the interview, students reported their awareness of the reason for their work "Yeah, Mental Health well being".

School 2: PowerPoint was used to share the learning objectives with students. The learning objective of clean and affordable energy was brainstormed by students using Mentimeter and breakout rooms (see Figure 3-4).

Figure 3-4 Sharing Learning Objectives with Students

School 1: The competences of problem solving and communication were observed being explained to students. Students volunteered answers on how they would be achieved, from "gathering information", "asking a question", "making a decision with their partners". These competences were iterated at the end of the lesson, with students using hand signals, i.e. thumb up, down or middle if they worked together with their partner, if they made decisions together, if they explained what they did.

School 2: Teacher 2's lesson plans and slides illustrate how students could achieve the problem-solving competence and what it involves. Web sites were also suggested to students by the teacher. Teacher 2 in his interview, highlighted how students shared objectives and competences with each other, in breakout rooms, and used Mentimeter to gather keywords.

> "There was a lot of reflection, what are they really asking, trying to really think simple, breaking everything down, all the learning intentions down, and learning objectives, what are we asked to do, what are supposed to do." (Teacher 2)

School 1: It was observed that students were aware of what they had to do. They discussed identifying trees by characteristics such as leaves, branches, height, bark and buds. They first researched what websites could be used to help. They shared their websites with the teacher and each other. Students identified a site that could identify the trees and the buds. (They realised due to the time of year, not many trees may have leaves). The teachers had already downloaded material from this site (but one group of students also discovered it). Students knew what was expected from them i.e. go outside, explore the trees on the school site and identify them using the handout. They also took a picture of the trees using the iPad. The teacher recapped the objectives at the start and end of each lesson.

School 2: Teacher 2 reported how students were involved in defining the success criteria and in discussing how they would approach the tasks. The success criteria were established from student and teacher collaboration.

> "I would have added my bit, so obviously it is kind of student-led, but obviously a lot of collaboration with the teacher. I would have had to filter out some things as well. But when it comes to maybe understanding the learning outcomes, we would have… I found the best two probably Mentimeter because it's faster, there's the code, well they can pick keywords putting things together from that as well." (Teacher 2)

As this class was not observed, and most of the work was student-led at home, it was unknown if students returned to the objectives when doing their project.

INTERDISCIPLINARITY OF STEM CONTENT

School 1 is a primary school thus the one teacher teaches all subjects. However, in this instance, the case study teacher job-shared and was solely responsible for the subjects Geography and Science (both teachers teach other core subjects). Whilst this teacher was supported by her principal, and received digital tools suggestions from a colleague, the ATS STEM project was conducted solely by this teacher. This teacher was also solely responsible for the development of the evaluation criteria and evaluation of her students.

Four science teachers took part in the study in School 2, with the students being taught during the year by the same science teacher. However, teachers did discuss the evaluation criteria collectively. They were aware that if students were not back in school after April 12th, the ATS STEM activities would need to be used to calculate the end of term mark.

> "Because, we may be relying on this as a form of assessment, as the end of the school year, because just in case if we're not back after April 12th, we've to take everything into account, the current second years, will the CBA they just complete it there, will we count that in, will we count cycle 1 and cycle 2 as 25% each, like we're doing with the current third years for their junior cycle." (Teacher 2)

Teacher 4 from the pilot school (School 4) highlighted how he worked with another science teacher, in setting up the Padlets for sharing, discussing and peer assessing their students' work. With each class having viewing rights to the other class's Padlet.

Interdisciplinary Content

In School 1, theoretical and practical knowledge of Mathematics was required to complete the sensory garden design, as students measured the area and made scale plans of the same (Figure 3-5). Art was also necessary to draw the initial garden plans, and arches.

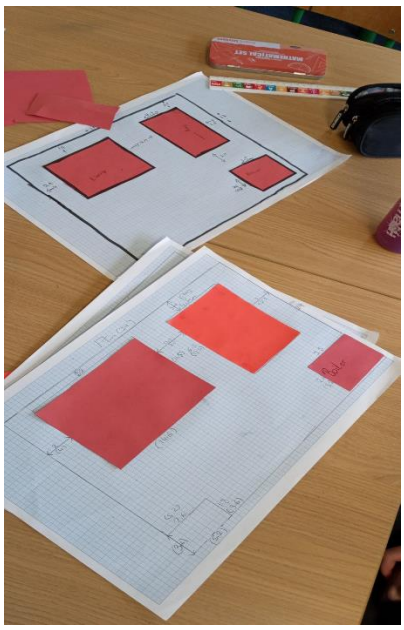


Figure 3-5 Student drawing scale plans for school garden

Art was necessary for Learning Cycle 2, as students had to draw a leaf or bud for their e-books. The teacher also brought other subjects into this cycle, such as History, Geography, and the Irish language. While interdisciplinary knowledge of these subjects was not necessary to complete the task, it aided understanding and helped students relate the importance of trees to where they lived. The old Irish language, ogham (Figure 3-6), had many letters named after trees. For Learning Cycle 1, mathematics was necessary to complete the tasks, and thus was a focus for the design of sensory garden plans to scale, see Figure 3-5. In the classes that were observed for Learning Cycle 2, some students were heard discussing how best to draw the buds. When creating their eBooks, Teacher 1 reminded them on the use of English grammar, and proper sentence construction.

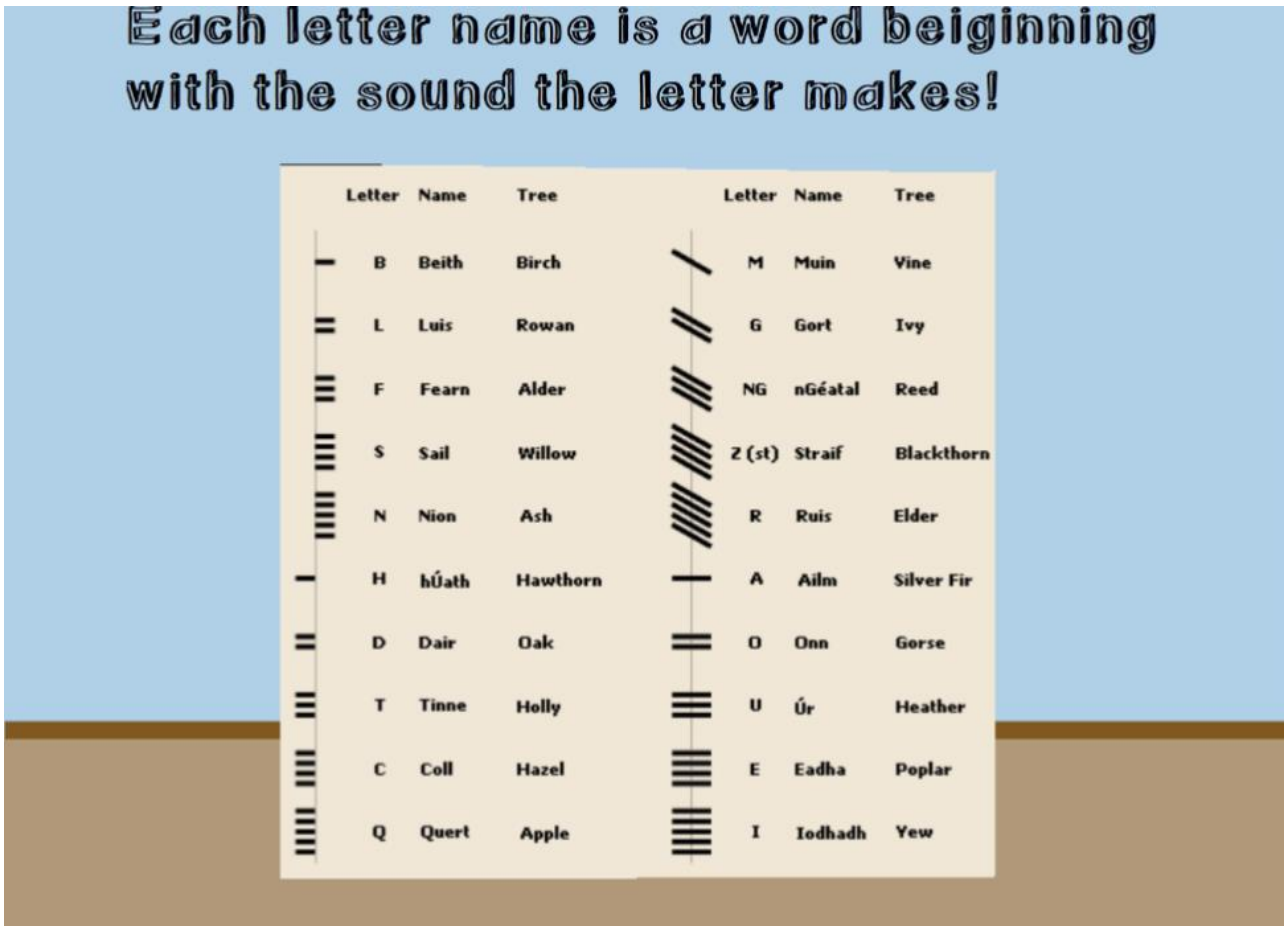


Figure 3-6 Irish language Ogham words for trees (Teacher 1 Class Slide)

At the interview students related how they were aware that they were using other subjects to complete their tasks.

> **Interviewer:** So, with those subjects when you were doing the science project here with the sensory garden. Did you use any of those subjects?
>
> "English."
>
> "We used maths."
>
> "Maths."
>
> "English and maths, yeah."
>
> "We were measuring the thing, the space."
>
> **Interviewer:** And any other subjects that you might have used?
>
> "Art, we did art."
>
> **Interviewer:** That's right because I saw – what were you doing? You were drawing, weren't you?
>
> "Yeah."
>
> "Geography."

Interviewer: Geography is used a lot actually. So, you said art, geography, maths… That's really good. So, you're using the maths for the measuring, the art was for the?

"Drawing."

"Drawing the buds."

"The geography was how we planted and where everything was and English for communication."

In School 2, theoretical and practical knowledge of CSP and Geography aided students when completing their Learning Cycle tasks on ethical and sustainability issues that arise from electricity consumption. Whilst knowledge on these subjects was not necessary to complete the tasks, they aided and complemented their science learning, as links to other subjects were made by the teacher. Teacher 2 also taught the class CSPE, and discussed the sustainability of energy and electricity consumption in that class, at the same time. In Learning Cycle 2, students' tasks concerned the effects of global warming on the weather and climate. This task was linked to topics such as water cycles in Geography, which were being taught at the same time.

We would have done a bit of energy, in first year, because we would have broken down energy, what it is, and the types in first year, and then we'll go more into it in second year, we adjusted the curriculum this year into energy conversions. And of course, because I would teach CSPE as well, so we would continue on sustainability in second year, because we do that in CSPE at the same time, and we do all about cycles, water cycles in geography at the same time, so we would interlink between the departments, thinking, when can we all link in at the same time. (Teacher 2)

During focus groups students also relayed how Technical Graphics (TG) helped with the project.

Interviewer: Did you need to use any of the skills you learn in those other subjects? Did you need to learn them? Did you use them in your science project?

"Maths, Geography & TG. Yeah, that's the main subjects we used. "

Interviewer: I just going to go back. So, I can understand maths and I can understand geography. How did the technical graphics come in?

"We had to draw a diagram of what we were doing. We could use that."

Interviewer: Thank you. And so, in XXXX group, the same question. Were there any skills from other subjects that you brought in?

"Obviously, there was maths and geography, that was really it to be honest. That was all I really used."

Whilst students indicated how they used interdisciplinary knowledge in completing their projects, how often they discussed and reflected on this is unknown (as no observations were conducted), however as Teacher 2 was teaching ethics in CSPE at the same time, and the Geography teacher was purposefully teaching water cycles, (to coincide with the Science learning), it can be assumed that it was quite often.

3.1.2.2. REFLECT STEM LEARNING DESIGN PRINCIPLES (AND SOCIAL CONSTRUCTIVIST VIEWS OF LEARNING)

School 1

The problems raised were connected to the real world, as the students were involved in designing a sensory garden and identifying native trees for a sensory garden located on the school grounds. Similarly, research was very much linked to

the real-world as students researched “sensory items” for the gardens and how to identify native Irish Trees. Students also researched how they would measure the garden (see Mentimeter) and identify native Irish trees. Technological or Engineering design was not formally discussed but elements of these processes were observed where students discussed the importance of trees. For example, Teacher 2 used Mentimeter to ascertain their answers (see Figure 3-7), into what trees are used for. Students also researched native Irish trees and their characteristics. They participated in a quiz to ascertain their current knowledge on the identification of native Irish trees. They then explored the school grounds, taking pictures of the trees. Their eBook creation was an iterative process, as they retook pictures or redid sketches if they were missing information needed for their eBook. “Yeah, we did research on trees to get like, how like say, like you seeing I don't know, a birch tree; you’d look it up and you'd find like information and you’d like, write it down your own words, if you get me.” (Student, School 1)

Figure 3-7 Mentimeter example

The problems or challenges identified by teachers and students were mainly with the environment, with Teacher 1 expressing difficulty with internet failure. She also highlighted timing, as she needed to train students to use the devices and applications. Students also needed email accounts, with the teacher having to create “temporary” accounts for them to use Book Creator. As iPads are shared with other classes, there were issues with students forgetting what iPad number they had used, and time was wasted trying to find their work. “I suppose the main thing was and you saw it yourself when the internet goes then, it kind of goes out the window and I was lucky yesterday in that it was just mine that went.” (Teacher 1)

COVID was also an issue, in that Teacher 1 wanted students to have measured the garden before they did their initial designs, but this was not possible. Instead, she measured it and videoed this, however students subsequently measured it when they returned to school.

Input from all team members on a problem was always encouraged by the teacher as the students worked in pairs, for all tasks in Learning Cycle 2. Collaboration was also a focused STEM competence for this task. Teacher 2 was observed

emphasizing to students that when doing the Blooket quiz, they work in pairs and both students had to agree on the answer. Teacher 1 encouraged students to pass the iPad when answering questions.

The trees students selected to use in their eBook and sensory garden were decided using their new knowledge of native trees. Learning Cycle 1, revolved around a design task, so students had control over what elements to put in the garden. Similarly, in Learning Cycle 2, students had control over how the book is designed, for example the pictures to use, text to write, images to draw.

School 2

The problems raised in School 2 were connected to the real world, as they dealt with the topics of energy consumption, electricity generation and climate change. When answering their ATS STEM questions students were asked to assume the role of different organisations such as the Local Council for Sustainable Energy Authority of Ireland (SEAI). Components of engineering design were observed. In Learning Cycle 1 students did not have to create or test a prototype, so engineering design was not applicable. Figure 3.8 below displays the problem solving tasks that students performed during this cycle.

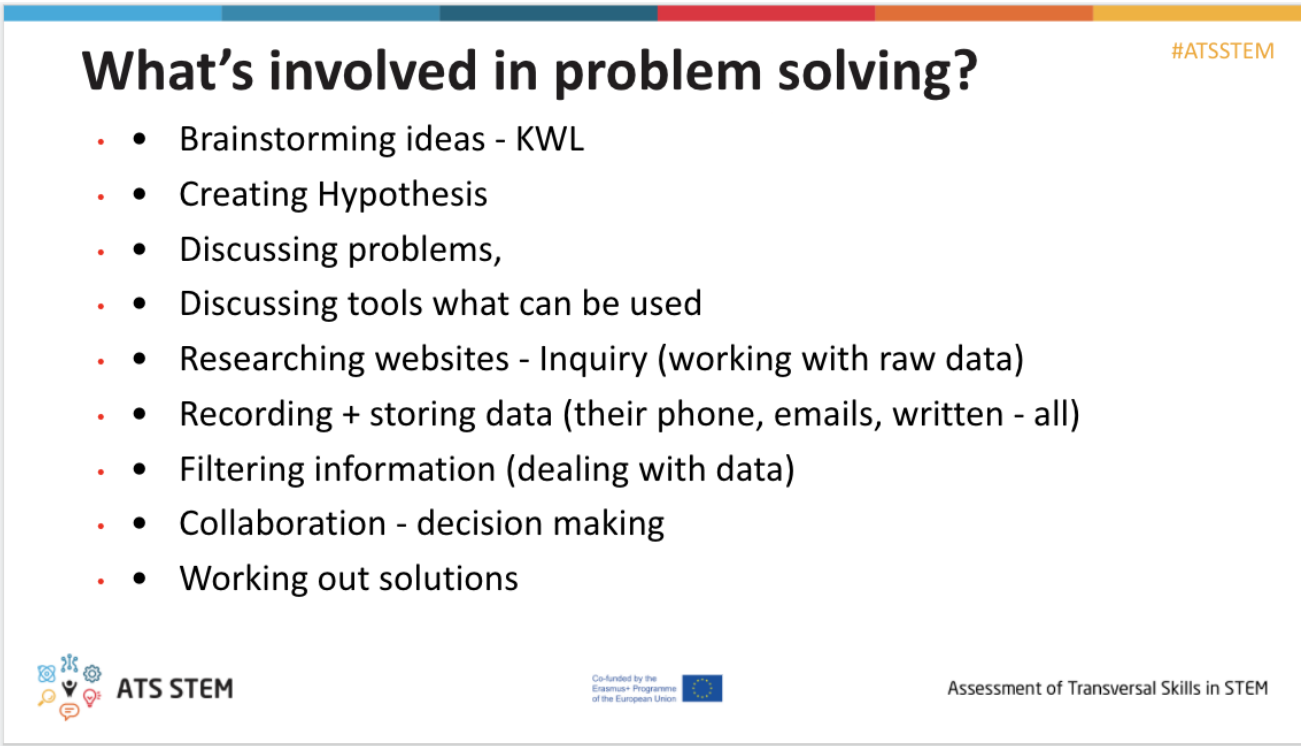


Figure 3.8 Teacher 2 class slide on problem solving

For Learning Cycle 2, students had to design an experiment, thus creating and testing their solutions was appropriate to the task. There was no evidence of refining or iterative prototypes observed in the provided three artefacts, as the experiments were conducted at home, this may have occurred but was not documented.

The problems and challenges articulated by Teacher 2 and students surrounded COVID-19. Due to COVID-19 students conducted the ATS STEM projects at home. The project was designed to be student led. Students were given the opportunity to do the work in groups. Most students did their projects for Learning Cycle 1 individually, but some did

their Learning Cycle 2 project in groups. However, five students (out of the six) at the interview had completed their project individually. Although one student mentioned how he had set up a WhatsApp focus group with his friends, as their projects were similar. Students did have one or two online classes a week, where they discussed in breakout groups their projects. "We worked in breakout rooms when we were on our calls and we could talk about the different things that we were doing for the project.". In Learning Cycle 1, students had to provide recommendations on electricity generation for their local area based on their research. Similarly, in Learning Cycle 2, students were encouraged to build their solution using new knowledge as research was an integral part to the design of their ATS projects and component tasks. In Learning Cycle 1, they were encouraged to bring their vision to real-life in that they had to make recommendations (they did not build a product). However, in learning Cycle 2 they had to design an experiment, based on their research.

REFLECTING SOCIAL CONSTRUCTIVIST VIEWS ON LEARNING

School 1

Due to COVID and subsequent lockdown restrictions, students' work for Learning Cycle 1 was individual. However, Learning Cycle 2 was taught in the classroom, and students worked in pairs. They worked together to answer their teacher's quizzes, explored the school ground in pairs or with their pod, and created their eBook in pairs. (Although Teacher 1 did indicate that her favorite teaching method is JigSaw, and she would have loved to use this technique with this project, this was not possible during COVID-19, as she could not change students from their pods.). Teacher 1 provided students with the tools to complete their tasks. As this was a design task, and design is subjective, the teacher allowed free rein regarding the style of the books themselves. Elements of the tasks were scaffolded, for example students could pick any four of the native trees in the school ground for their eBook, and they could choose what characteristics of said tree to describe. In reference to collaboration, Teacher 1 reported that:

> "No for learning cycle one they didn't have much collaboration at all so I tried to put it in as much in this one so definitely group work is one of the focuses for the second one and they're working in pairs and they'll continue to work in pairs." (Teacher 1)

Teacher 1 encouraged each member of the pair's active commitment and provided students with an assessment to ensure they collaborated and communicated properly (see Peer Assessment). As discussed earlier, Mentimeter (information sharing), Blooket and Book Creator (information sharing and building) were the tools used to foster cooperation (see 3.1). While cooperation is not inherent in the Blooket application, the students used the application in pairs. Zoom was also used, but that was due to lockdown, and to facilitate the online classroom. The teacher was the sole 'team' member of this ATS STEM Project, and thus team evaluations and sharing with different teams is not applicable.

School 2

Due to COVID and subsequent lockdown restrictions, students' work for Learning Cycle 1 was individual, however some students did the project work in Learning Cycle 2 in groups, and as mentioned earlier, one student, who was working individually set up a WhatsApp group, with students doing a similar project. The discussions in the online classroom were group-based. Whilst most of the project work was completed by students in their own homes away from the virtual classroom. Teacher 2 facilitated the group based online discussions, by organising breakout groups in his online classes. At the interview, the one student who participated in a group indicated that they were responsible for the work themselves and worked autonomously. The point should be noted that the ATS STEM projects were not the only focus for students at this time, they also had The Irish State Exam CBAs, and discussion on this topic was also a focus for online classes. The online classes were not observed, thus the question "Does the teacher encourage the active commitment of each and every member of the classroom?" cannot be answered. Mentimeter (information sharing), MS Teams whiteboard and breakout rooms (communication), were the tools used to foster cooperation. Students in School 2 had autonomy in decisions about their own learning process in that Learning Outcomes were collectively devised and students decided on

the experiment to best illustrate their experiment to highlight the effects of climate change. As a lot of students did their work individually (due to lockdown), it is unknown whether team evaluation is encouraged, however peer assessment of students' previous work was conducted. Students shared and evaluated previous work when Task 2 was being conducted, work from Task 1 was shared and graded as the evaluation criteria remained the same (based on the NCCA guidelines).

STIMULATING CREATIVITY TO OFFER MORE THAN ONE SOLUTION TO PROBLEMS

School 1

It was observed that the classroom was a safe environment for students to express themselves without fear of making mistakes. When asked, students indicated that if they made a mistake you would just "Rub it out." They also stated that they did not mind making mistakes. The tools used in the classroom for formative assessment were anonymous, in that Mentimeter does not relate the displayed answers to a person. "Yeah, I'd normally don't really like anonymous, kind of like when I used to play Among Us, I didn't like anonymous voting but Menti was different. Fun." (Student, School 1). Students indicated by a show of hands at the interview that they would prefer Mentimeter to stay anonymous. While Blooket identifies the number of incorrect responses, it also does not relate them to the person, however it does show a leaderboard. Students observed that they were not alone with the incorrect responses, and comments were made on the same. Teaching or discussion of failure, or errors being indispensable to the learning process was not observed, but students would get up and go outside to take more pictures of trees if they made an error, it was not considered an issue. Also the teacher was observed telling students she did not know an answer and that they would have to ask other students, this was in relation to bud identification. Both Learning Cycle tasks concerned design, thus students had room to explore their own insights as shown in Figure 3-9, and the tasks themselves encouraged creativity. Students engaged with the features offered on Book Creator, with some students submitting pages with songs and digital art (instead of pencil sketches) in their books. They were also observed trying out the screen readers etc. The teacher had not been aware that the tool offered these features.

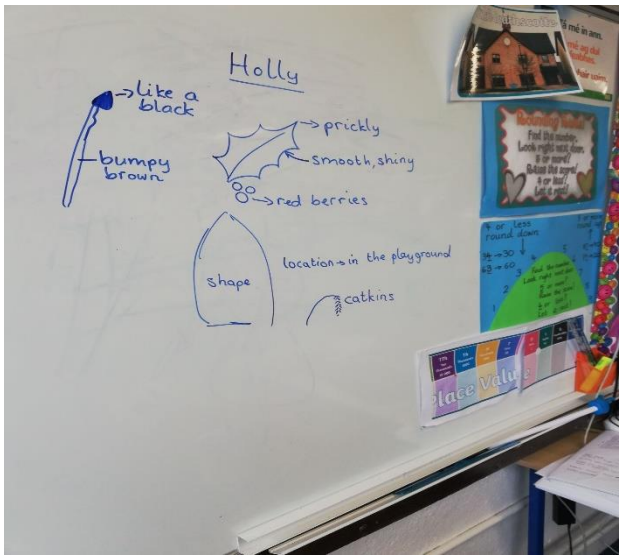


Figure 3-9 Student work-depicting a page for their ebook. Figure 3-10 A photo of the whiteboard in School 1 which depicts the characteristics of a Holly tree. This description was used as an exemplar by students when documenting the characteristics of the native trees they selected.

Most students felt they would not use the knowledge taught in the activities outside of school when asked. With reference to the activities motivating students to explore new knowledge, this was not really observed or recorded, however one student stated that they might use Book Creator again to create a book at home, and another stated 'I like Blooket and

that sometime I'd like to host a game on it or something'. Both Book Creator and Mentimeter allowed students to share their ideas, with Book Creator allowing work to be shared. As stated earlier, there were no work teams involved in this case study school.

School 2

Whilst project work was conducted in the students' own homes, students did state that they found the online classes and breakout rooms helpful for gathering ideas. The teacher also verified he had no issues with conflict between students. This would indicate that the online classroom was not a place that students were frightened of making a mistake. At the interview students indicated that they willing shared ideas, and they presented their work to the class and in their breakout rooms. No data was gathered to indicate the teaching that errors are important to learning. No data is also available to answer the question 'Does the teacher encourage critical thinking by questioning the origin of his or her thoughts or ideas?'

Students were asked to design a simple experiment at home showing the occurrence of global warming/climate change. Students demonstrated innovation and creativity coming up with a hypothesis and planning a small-scale experiment. The topics chosen were diverse and they photographed, and video documented the process for assessment. The students also presented their ideas with PowerPoint presentations for the class leading to discussions and feedback (Figure 3-11).

Students came up with various methods to combat greenhouse gases at community level, planning efficient energy conservation in Irish homes. Though common themes were prevalent due to the chosen Sustainable Development Goal, students still managed to offer a considerable number of interesting unique solutions for combating climate change.

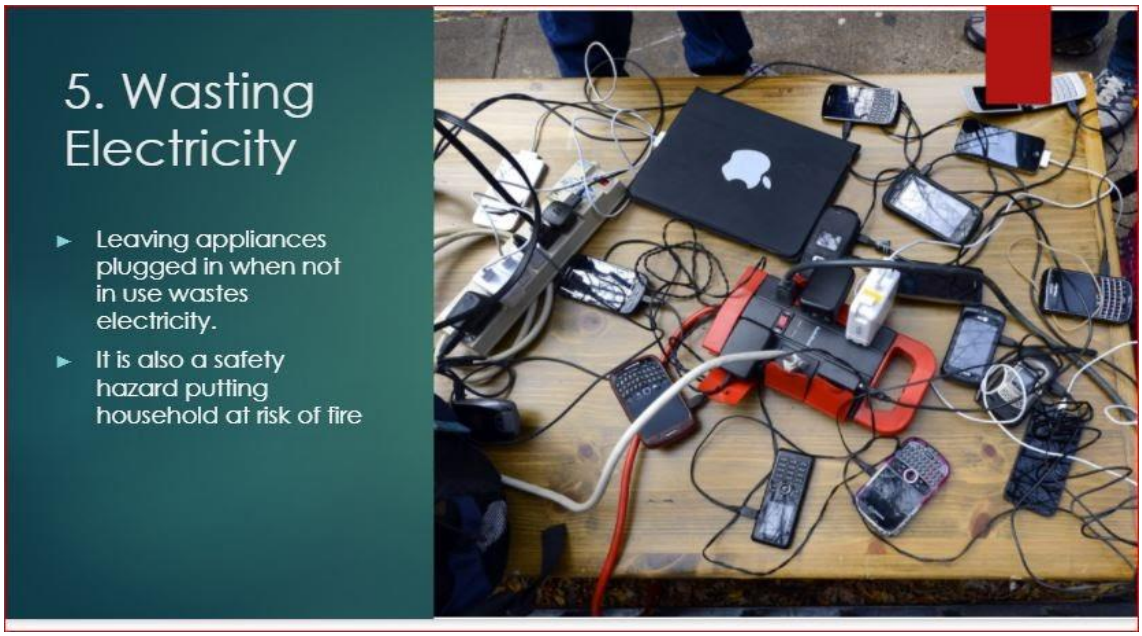


Figure 3-11 Student Slide illustrating one way that electricity is wasted

Students appreciated learning through digital tools as it gave them the opportunity to research via other channels like YouTube. The change of pace from the traditional book centric approach stimulated further creativity and problem-solving skills.

> "It was good because it was a different way of learning. We weren't just using our books all the time and we used like teams, one note and we could research, watch YouTube videos on it. So, it was nice to have a change from just the books."

3.1.2.3. FACILITATE FEEDBACK (IMPROVE LEARNING BY PROMPTING THE LEARNER TO USE EFFECTIVE FEEDBACK FOCUSED ON THE LEARNING OUTCOME/GOAL IN A TIMELY MANNER

School 1

The teacher was observed giving students verbal feedback throughout the creation of their identification of native Irish trees and creation of eBooks. This feedback related to the work they were doing and to the requirements of the task. Students were observed asking questions on the same. It was also observed that students were given the opportunity to clarify if the trees they had selected and photographed were native Irish trees. For example, one group had assumed an apple tree on the school ground was native to Ireland. The teacher explained that it was only crabapples that were native to Ireland, so they had to search for more native Irish trees on the school grounds. There were eight different types of native Irish school trees on the grounds. Feedback was also given to students through the use of the Blooket quiz and Mentimeter as described earlier. Students were asked about feedback in the focus group. They stated that they knew what they had to do. "Well, miss would say like, you have to have pictures of the trees, then some information, then like maybe bullet points, if you get me like, saying how tall they are, how small they are." The students completed their ebooks in class over two lessons. The learning objectives and tasks were explained and discussed with all students during both classes. The teacher provided oral feedback on their e-books in respect to meeting the objectives and layout. She would visit each group, keeping them on task by asking questions, getting progress reports, and giving feedback. Teacher 1 gave positive feedback that helped with clarity. During their focus groups, students indicated different adaptations of this feedback. Some took feedback on style, others were more reluctant to.

> **Interviewer:** So, she came around to you and she'd have a look to make sure you were doing it?
>
> "Yeah."
>
> "Yeah."
>
> **Interviewer:** So, you kind of got feedback there and then and if your teacher gave you some feedback would you change what you were doing based on what she said?
>
> "Like I'd do a little change, probably like I wouldn't go and change the whole thing though. I'd try and just change it without like leaving everything and then starting again like."
>
> "Well depends on the feedback. If she said make the text bigger but I liked how it was I wouldn't change it but if it was like move the picture so you have more space for text then maybe I'd do that."

The above quotes indicated how Teacher 1 made students aware of the tasks they had to perform and that her feedback was task-centered. Students also indirectly received feedback as they saw examples of other students' books on the interactive board. The Blooket tool was used for students to test their knowledge on identifying various trees, the tool provided immediate feedback as it would show the correct answer. Students were also able to ascertain their progress as the teacher did a pre and post test of native trees using Blooket.

School 2

The students had MS Team calls for each subject and they would discuss their topic for the task be it group or individual work. The teacher was noted to have received drafts of student work in different phases of the activity. The students were given feedback based on their individual topics. This sequential feedback structure was observed for most of the students who made changes based on the feedback received until a final draft was ready for submission:

> "Like we almost sent in drafts of research halfway through. And then were told what improvements we can make. And then we went back and repeated it a couple times and then at the end we're given some overall feedback. Yeah."

An example of feedback provided by Teacher 2 is shown below. This feedback example illustrates how the feedback progresses students towards the objective set, provides contents and strategies to improve the work or the evidence presented.

> Well done XXXX– Nice tone to Task one, please note the following:
>
> A) Clearly followed the success criteria and planned out task quite well following directed website
>
> B) A clear informative recommendation for Solar Energy for XXXX is stated well
>
> C) Maybe look a little at formatting headings e.g. Pros + Cons of each source of renewable energy – highlight it so it sounds out more to the reader. (Teacher 2)

Students were however free to decide on whether they wished to receive feedback and whether or not they chose to implement it. Students also noted that the feedback effectively addressed the issues raised while completing the task. Overall, most of the students found the feedback helpful and precise and followed recommendations of the teacher. It is of note that not all students expressed interest in sequential feedback and would rather complete the assignment on their own before submitting for marking.

> "I wasn't really sending my work on, I done it all at one bit and then I would send it on to him. But I kind of like to focus on and do it my own way."
>
> "100% yeah, we did change it. Well, I think it's good because we got told exactly what we needed to change. Which is, yeah, that was the good thing about it. It was precise feedback."
>
> "Not really. If I was struggling, I'd send it on to my teacher and asked what he thought, but aside from that then, I just kind of do it and then send it to him and he sent me feedback and then if I need to change anything or it's grand now."

Students were given a list of clear success criteria that they could go through and refer while working on the task. Students were all provided with relevant feedback based on this success criteria. Students noted that they assessed their progress in line with the list of criteria. Students also used the Assignment Tab in MS Teams for submitting and receiving feedback on their drafts.

> "In every project, we were given a list of success criteria, almost like a checklist to go down and true and take off all the boxes. And it was like available for everyone to use."

MS Forms was used to elicit feedback from the students on the assessment process. The teacher created a survey to ask students what form of feedback they preferred. Most students responded that the feedback was useful and while half of them preferred written feedback, the other half preferred mixed feedback with both written and verbal engagement (Figure 3-12).

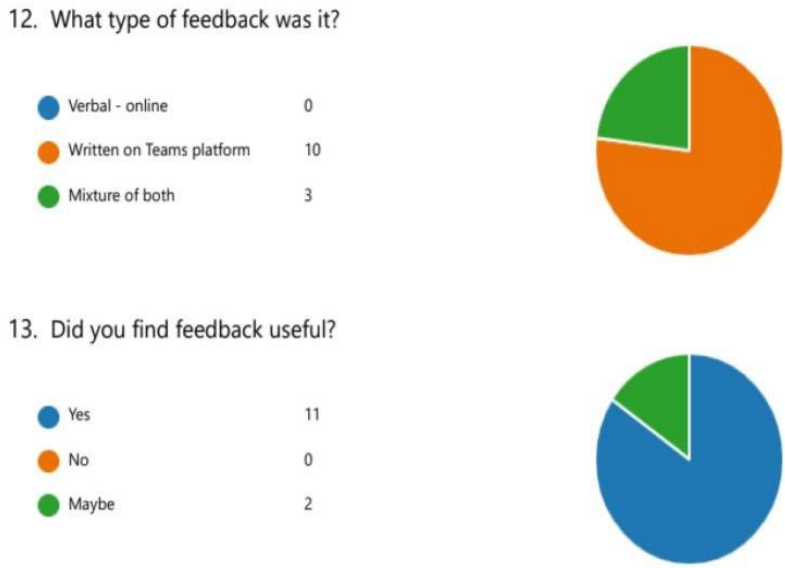


Figure 3-12 Student feedback preferences and usefulness

Students were also asked about their experience with digital tools and assessment. Most of the students felt that the use of digital tools made the assigned task easier and also admitted to being comfortable with using digital tools before starting the task. Finally, formative feedback that included cognitive assessment was used in Learning Cycle 2, through the form of a Kahoot quiz.

FEEDBACK RELATED TO SELF-REGULATION

School 1

In Learning Cycle 1, Teacher 1 provided students with a rubric that allowed them to evaluate if they met the criteria for the task, designing an arch. This rubric (and design task) was introduced after Teacher 1 realised that her success criteria for designing a sensory garden was too vague. The plans students returned were "really flat and I wanted them to be more, you know, kind of raised, maybe arches, things you walk under" (Teacher 1). She stated that if the students were at school, she would have fleshed out their designs more. For this reason, the teacher conducted a second task in Learning Cycle 1: design an arch for the garden. She gave the students specific instructions in that the arch had to use two senses, be creative and incorporate some Irish history or Celtic theme. Figures 3-13 and 3-14 show two examples of work returned from this task.

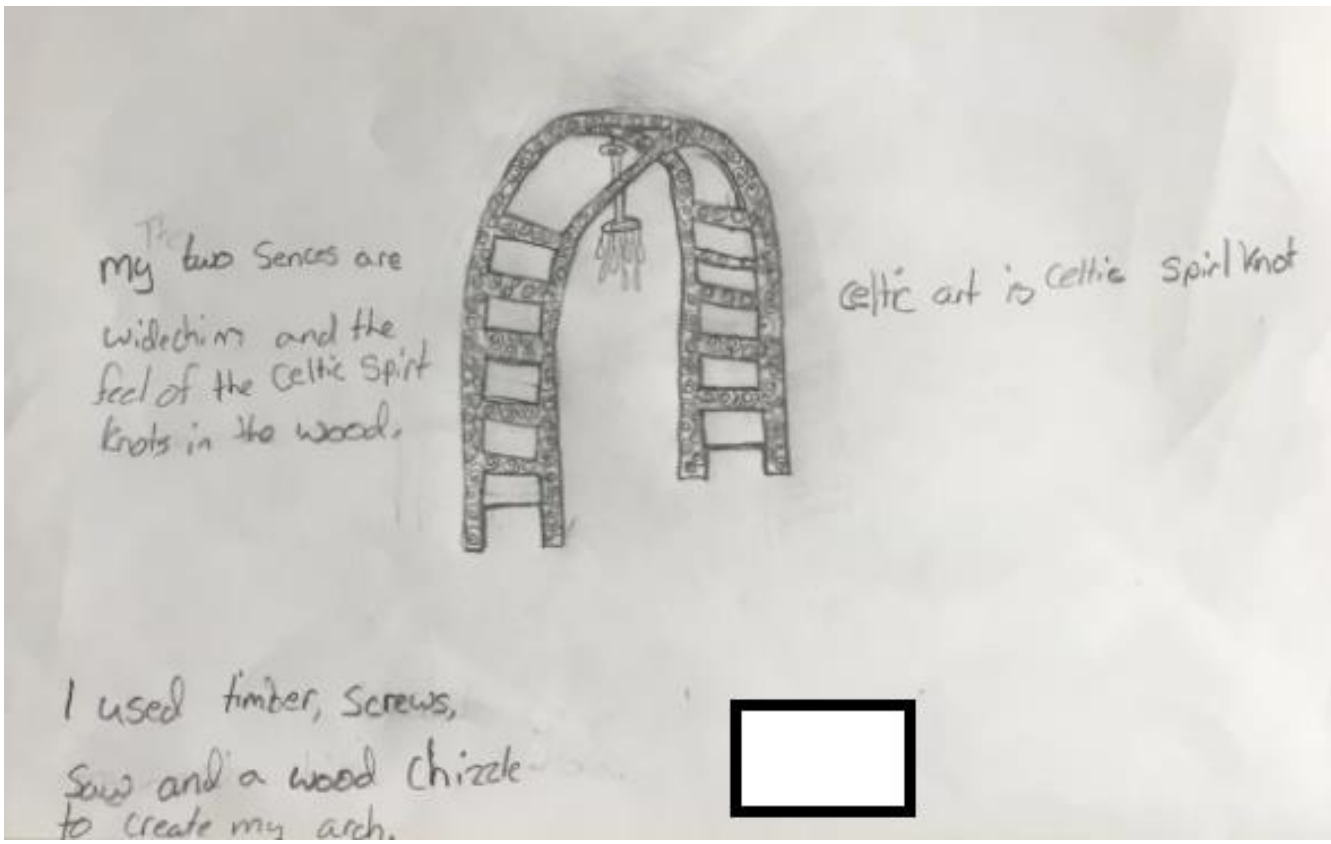


Figure 3-13 Student work on garden arch – example 1

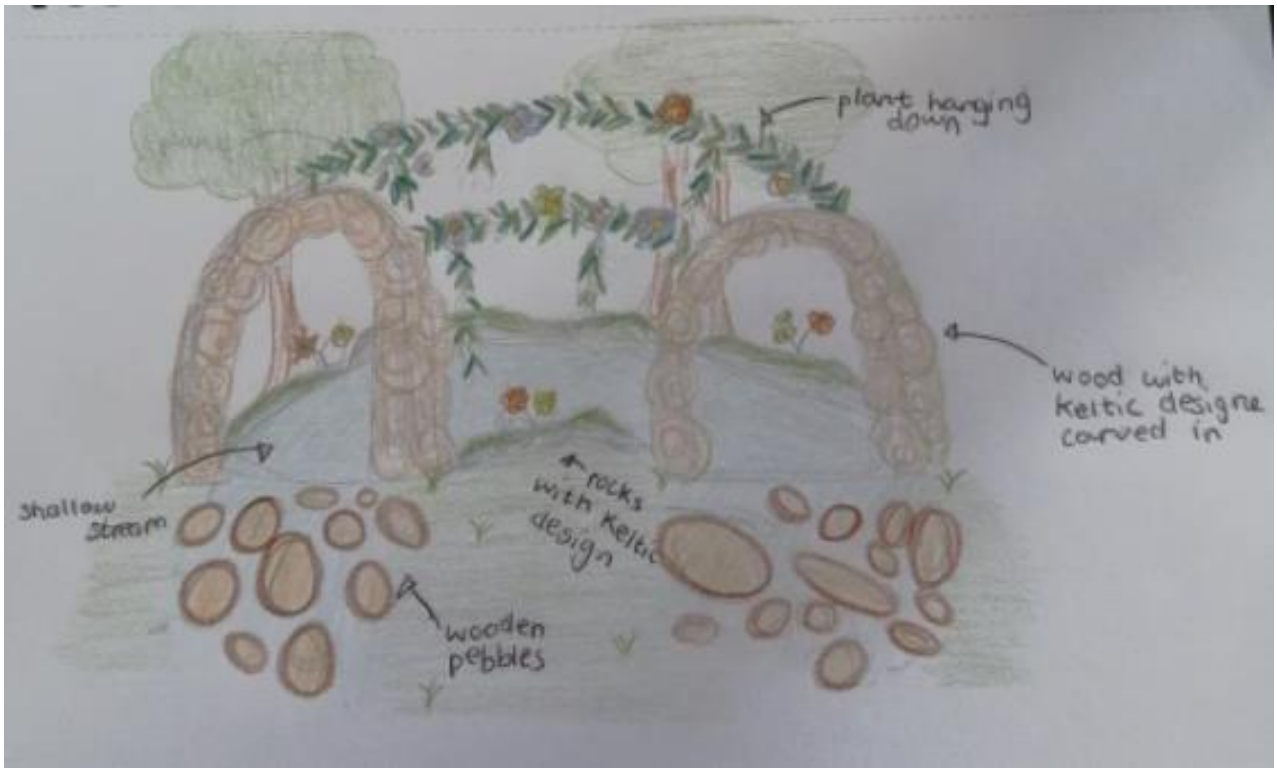


Figure 3-14 Student work on garden arch – example 2

The feedback observed in Learning Cycle 2 was via Blooket and Mentimeter. Feedback to propose strategies to improve learning was observed as students were reminded by the teacher during the class how to problem solve, communicate successfully and use technology (see Fig. 3-15). Hence this could be seen as a form of "feed up" aspect of feedback where the students are reminded of the ultimate goals (Hattie & Timperley, 2007). Feedback that contained in-depth information was not directly observed.

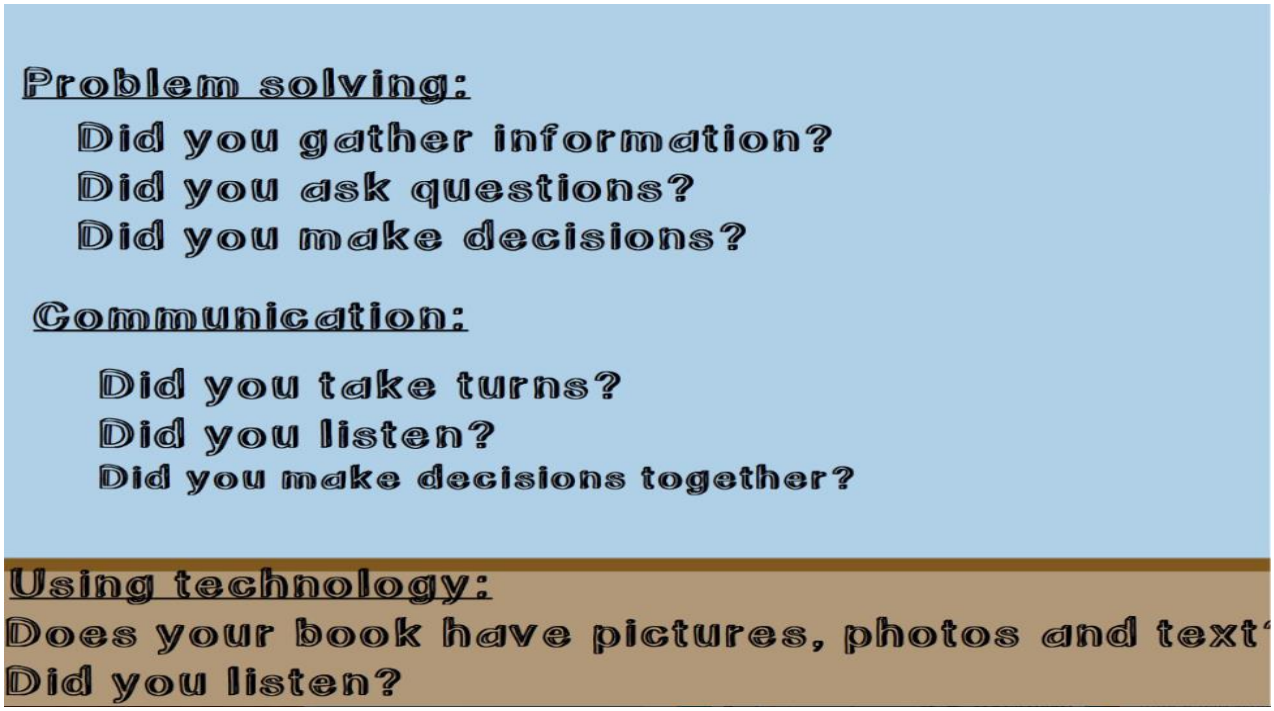


Figure 3-15. Feed-up feedback. Class Slide from School 1 which illustrates how the teacher reminded students of their learning goals.

The pre- and post-test using Blooket provided context (time of achievement) to acquire knowledge, with one student stating (see 3.1.1.1) how they went and learned the native trees so that their score would improve.

School 2

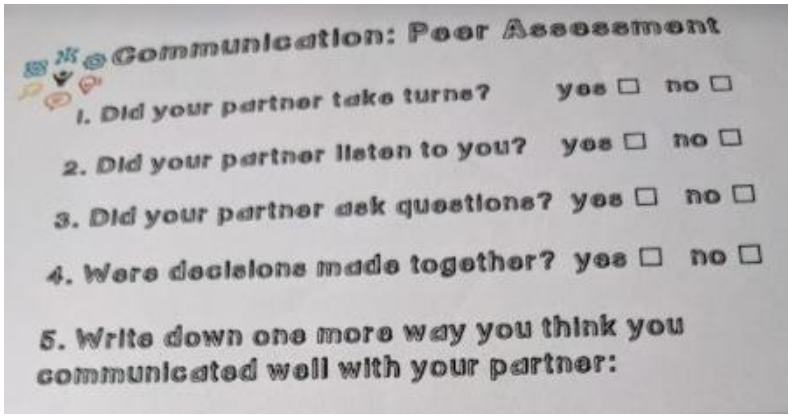
Students were provided with success criteria to evaluate their own work, see Chapter 1. Due to COVID-19 lockdown, the projects were student-led. The assessments thus facilitated student learning autonomy, as students worked on them at home, during school timetabled science time (when online classes were not scheduled). The observed written feedback did not contain strategies for improving learning, it was task orientated around the format "two stars and a wish, the two good things about it and then obviously the one… how can you improve this the next task" (Teacher 2). However, such feedback may have happened as students indicated by survey that their feedback helped them improve.

As stated above the feedback did not contain in-depth information, but students indicated that it would help them in the future. However, as peer assessments were not observed,in depth feedback may have been provided there. A Kahoot quiz was performed in Learning Cycle 2, which allows students to generalise the knowledge acquired.

3.1.2.4. FACILITATE PEER-ASSESSMENT (IMPROVE LEARNING BY ACTIVATING STUDENTS AS INSTRUCTIONAL RESOURCES FOR ONE ANOTHER)

School 1

Students being instructional resources for one another was observed in School 1. Whilst peer assessment was not formally integrated into Learning Cycle 1, it was integrated into Learning Cycle 2. In Learning Cycle 2, students assessed their partners on their collaboration in the project. This peer assessment activity was a solo endeavour, where one student assessed his partner, and vice versa. This assessment was conducted using a paper checklist, not a digital tool. One of the STEM competences for Learning Cycle 2 was collaboration, and students filled out a checklist to evaluate how well their partners collaborated with them. This assessment was filled out periodically during a particular lesson, where the teacher asked the students every ten minutes to answer one of the questions depicted in (Figure 3-16). "Miss put something on the board, and then every say five or ten minutes she'd ask this one question then should move on to the next one, 10 minutes later. Yeah, then like 5 minutes later she would move on to the third one".



Fire 3-16 Peer assessment rubric for students (School 1, LC2)

The teacher did not grade the students for Learning Cycle 2, however the checklist consisted of the learning objectives such as taking turns, asking questions, and listening. No rubric was provided to students, they used the aforementioned peer assessment checklist. Students did not provide formal feedback on the learning process to their peers, however the provided checklist indirectly provides confirmation of communication learning achievement. The teacher was observed finishing each class with a recap and reflection on the work that was done. The peer assessment checklist also had a reflective question.

Coupled with peer assessment was peer learning. Two students were very knowledgeable on trees and were observed providing clarification to other students and the teacher, on the identification of buds.

> "The children themselves though it is a bog area, it's a kind of farming area so some of the children as you saw Colette some of them know like ten times more than me about trees about birds about like they're just amazing, some of them are amazing like the two days, Monday and Tuesday I was probably asking two of the boys, are we sure this is the you know maybe the hazel, that one I didn't know and he was sure and he was able to describe exactly you know why he knew it was the hazel so yeah I think they're experienced in outdoors because of the area they're from." (Teacher 1)

School 2

In School 2, students provided feedback orally in online breakout rooms on students' current work. "We worked in breakout rooms when we were on our calls, and we could talk about the different things that we were doing for the project." Peer assessment was conducted in school 2 using previous task submissions (which were already graded by the teacher). Students would peer assess this work. "...when we were in our live class would be showing an example of someone in the classwork anonymously, and kind of like other group, peer assess one piece of work and kind of like pick up the good things

and pick up things that could be improved on.". Students would grade this work, using criteria similar to the Irish Junior Cycle CBAs, which have four descriptors in their rubric: Exceptional, Above expectations, In line with expectations, and Yet to meet expectations. Teacher 2 stated that this way he could gently push students to do better. As the online classes were not observed, the type of feedback in respect to it being related to the learning process or the learning achievements of their peers is unknown. Students were given time to reflect on their work at the end, with one student stating how, when reflecting on the work he had done, he became more cognizant of the skills he had learned.

> "We knew about the skills but at the end of the project, when we were just talking about how it went, we learned more about it, if that makes sense."

3.1.2.5. FACILITATE SELF-ASSESSMENT (IMPROVE LEARNING BY ACTIVATING STUDENTS AS OWNERS OF THEIR OWN LEARNING)

School 1

Whilst students were not observed being involved in the assessment process, they indicated at interview that they could if "they wanted to" tell the teacher to change the assessment type.

> **Interviewer:** Could you say 'Miss we want more Blooket, we want more Menti', could you say things like that?
>
> "Yeah.
>
> "Maybe. I'm not sure."
>
> "I mean if you wanted to."
>
> "Yeah."

They also indicated that they understood the meaning of evaluation and related this to their checklist and completion of tasks.

> "Well, miss would say like, you have to have pictures of the trees, then some information, then like maybe bullet points, if you get me like, saying how tall they are, how small they are. What their leaves mean, like how to find out what. And their buds. Thunderbolts, yeah? I know that, I think it's like to Hawthorne bud, off by heart. Now I know that has a green stem goes purple in the Autumn and goes this and that."

Teacher 1 showed students the scores from their Blooket quiz on the boards. This caused a behavioural change in some students, as they were determined to do better when the quiz was repeated.

> "We kind of got to learn. Yeah, I learned all the trees off by heart then so I'd be quicker to do it."
>
> "I think Blooket is like good because when we did it, we did like a few rounds and we all liked but then quite a few people had a chance of winning it."
>
> "Yeah, it was exciting even if you were at the bottom because then you were battling not to finish at the bottom a bit so."

Students were aware of the success criteria for their tasks. A rubric/checklist was provided in Learning Cycle 1, so they knew the criteria for designing their arch for the sensory garden (Figure 3-15).

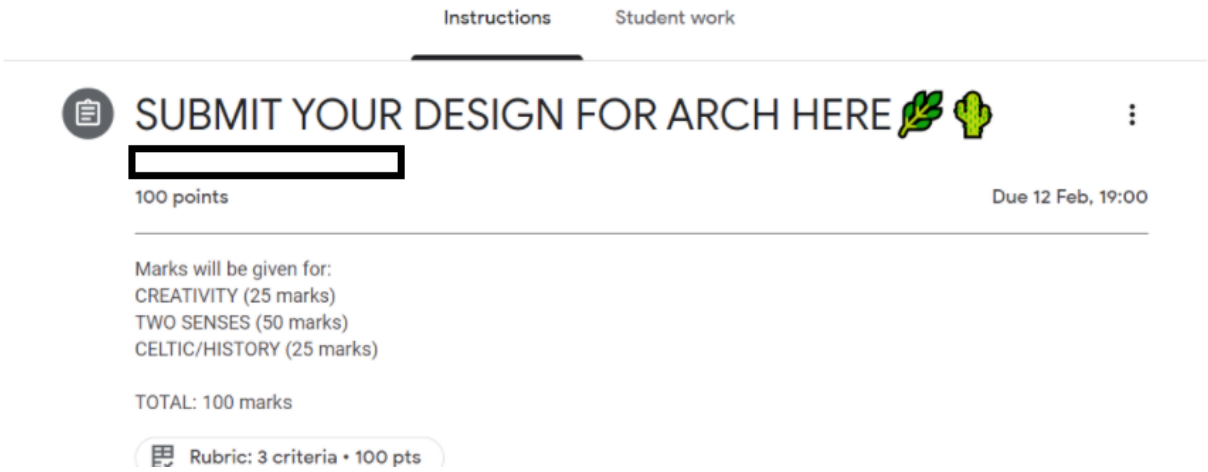


Figure 3-17 Rubric example for designing an arch (School 1, Learning Cycle 1)

A rubric was not provided for Learning Cycle 2, but the teacher illustrated the success criteria on the board and students were aware of the same. Teacher 1 was cognizant that as this project continued, she had to narrow and become more specific with her criteria, as the children needed to be scaffolded and to know exactly what was required of them (see Figure 3-10):

> "… it wasn't really 'til they started that I realise what I wanted you know to be more specific and that's exactly what I wanted. So, little kind of diagram, a little description of it, to help them realise and then a photo, they'll eventually put the photo in there of the ash tree that they found too." (Teacher 1).

Teacher 1 was observed in the classroom checking in regularly with students as they worked in pairs to ensure they met the objectives. Students also indicated they were aware of the work they had to do. At the interview students identified what they had learned and indicated that they would be able to grade their own work. They also attributed their learning and work to their effort:

> "I could give it a grade yeah, give it a grade. Yeah, I would love to do." "Yeah. I'd give it a grade. That's all I can say really. Maybe like." "Well, I'd be honest with myself if it's good or not so like I wouldn't be thinking it's brilliant even though it's not very good."

One student in his answer to the question, would you be confident in the grade you give, highlighted how he was aware his self-assessed grade was a reflection of his work.

> "I didn't put enough action. I did everything that I was supposed to do, but I didn't go over the top."

School 2

Students were actively involved in the assessment process. As previously detained in 3.1.2.3 above students were involved in setting the learning objectives and success criteria. Students were aware of these success criteria. One student stated in the reflection page of her project that "I found it helpful to know the success criteria because I knew what was expected of me and the project." Teacher 2 introduced developed students' learning by getting students to discuss and grade previous assessments. He also submitted a survey to students to ascertain their feedback on the assessment process. Of note, students preferred feedback to be from a mix of sources and found feedback helpful (see 3.1.2.3 above).

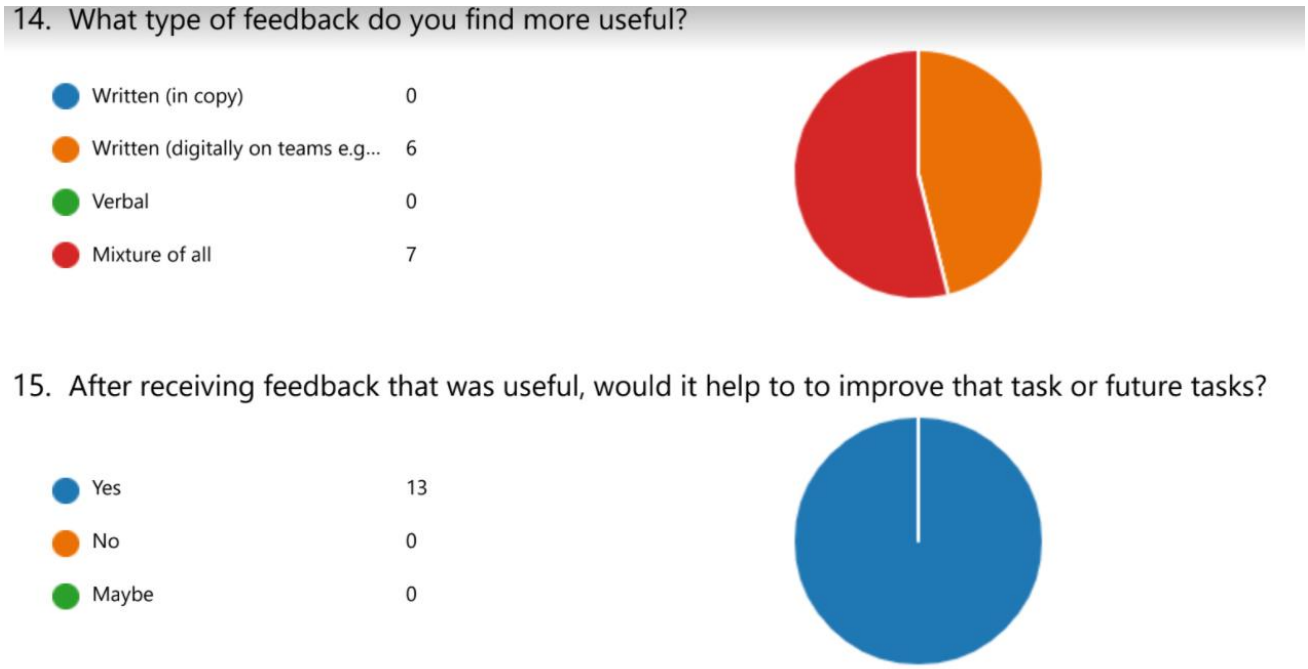


Figure 3-18 Feedback preferences

Students were aware of the evaluation criteria, as it followed the same criteria set by the National Council for Curriculum and Assessment (NCCA) for the Irish Junior Cycle Assessment. Students were also judged to be competent in understanding and grading their own work. In the focus group, they specified that they had the list of what they had to do and did it. "In every project, we were given a list of success criteria, almost like a checklist to go down and true and take off all the boxes. And it was like available for everyone to use." (Student, School 2) "Well, I would think, when I hand this into my teacher, I'm expecting this," (Student, School 2). Their artefacts illustrated that they understood what they learned, as it required students to make recommendations based on their research, for example which was the best energy to use to generate electricity in their local area. Some students also provided reflection on their learning: "My favourite source of energy was biomass. I found this energy very interesting to learn about. I think the best energy for [my county] to use would be wave energy, as we are a coastal county.", "I recommend for Ireland to build new houses with solar panels which will be very useful to make the house eco-friendlier and sustainable. In Ireland it might not be as sunny as in Spain but we do get a lot of sun regularly." Students were aware that they could avail of the feedback Teacher 2 offered to change or add more content to their work. However not all students availed of this option, even though they were aware of the consequences.

> "Like we all sent in drafts of research halfway through. And then we were told what improvements we can make. And then we went back and repeated it a couple times and then at the end we're given some overall feedback. Yeah."

> "I wasn't really sending my work on, I done it all at one bit and then I would send it on to him. But I kind of like to focus on and do it my own way."

3.1.2.6. HELP TO ELICIT EVIDENCE OF LEARNING (IMPROVE LEARNING THROUGH QUESTIONING AND DISCUSSION AND BY PROMPTING ACTIVITIES THAT CLARIFY THE MEANING OF SUCCESS)

School 1

Students were observed asking questions and contributing ideas collectively using Mentimeter and in class discussions. The book creation activity was designed to ensure contributions from all students. The eBook was designed in pairs with students sharing an iPad. The students swapped the iPad with their partner during the tasks. The students were observed researching, planning and executing their projects. As the students were just back in school after a three-month lockdown and the activity was new to the students, Teacher 1 found she had to scaffold the tasks for students. Students were observed discussing the characteristics of a tree, such as leaf, bark, buds etc., but the teacher found she had to be specific on how many characteristics they were to show in their books. Students were observed working together and supporting each other. They helped each other when they were on the school grounds to identify trees and measure the space for the sensory garden outside. One student reported how his group and another group shared information to complete the measuring of the garden, as both groups had done two different sides.

> "When we were measuring it, I remember I shared my information with XXX she shared some information I got that he didn't have. And then we were like the first ones done because her group did two and my group did two."

Figure 3-19 Student group work

Unfortunately, they could not support each other during lockdown, when completing a task. However, for Learning Cycle 2 the students worked in pairs and supported each other (Figure 3-19). While creating their eBooks they filled out a checklist, a peer assessment of their partner's collaboration. When researching and gathering contents for their eBooks, students were observed explaining to each other where certain trees were located in the school grounds and what features identified the trees as being a certain type. They also had a handout to aid with this task. Students were observed sharing the work and at interview, described the process:

> Interviewer: And when you were working with your pairs creating your books, how did you decide who would do the work?

> "Well. You split it. Half and half. You's let one person do it for like 10 minutes and the other person is like 10 minutes. You'd share, kind of share the iPad because you didn't have your own personal one so you share the iPad. Say it was me and XXX doing it. I did the kind of, say the first, the cover of the book and then the first page and then I'd give the iPad to XXX and she would do the next two pages and it will just continue on from there."

The tasks were sequenced and coordinated in that students researched native Irish trees first and then sketched and photographed them on the school grounds, before they started creating the books. Although they were free to leave their desks during eBook creation and go outside to retake photographs or take new photographs as the tree they captured may not have been a native Irish tree. At the interview the teacher spoke about some conflict that arose, with one student taking over and not letting his partner do the work. She also spoke about two instances where one partner was off task, when they were outside, and the other student was not comfortable saying that they need to get back on task and "take some photographs, no emoji" (Teacher 1). Teacher 1 also highlighted that with the pod structure, there were some pairs she could not change, and in one case there was a student of high ability who wanted to do all the work, and the other student was happy for him to do so. The teacher was observed checking each group to ensure the work was shared, which would ensure the other student had taken part. In one instance, she was observed, asking a student to show his contribution and then ensuring he participated equally. Teacher 1 stated how her preferred teaching method is JigSaw, but with COVID restriction this was not possible. At the end of the lesson, tasks were recapped, and the learning tasks were reviewed.

At the start of each lesson, the teacher reviewed with students their previous learning and how it related to STEM competences and sustainable goals. At the interview, students relayed that they had learned how to identify trees, use technology, and work with a partner:

> "I learned the different types of trees and different types of trees. I learned how to add, like the measurements."

> "Work as a team. I learned how to use technology a bit more. Like making books digitally. And I'd say working with your partner more. I can't think, working with your partner kind of, better in a way, if that makes sense. Because for me, I'm partially like independent. I want work by myself that makes sense, but it was fun to work with a partner because then you get to see different perspectives and stuff like that."

> "I mean I learned about how to use Blooket and stuff like that and Book Creator but I also know how to identify some trees now which I wouldn't have known before."

> "Well, I learned how to identify trees and I learned that I like Blooket and that sometime I'd like to host a game on it or somethin'."

School 2

Students were encouraged to participate in discussions around the chosen topics. Mentimeter and breakout rooms were used to fuel student participation. A survey was given out to elicit student responses to the use of digital tools and assessment. Students also reported use of Zoom and WhatsApp as well as Mentimeter for discussing ideas:

> "We used Mentee quite a lot to get a keyword on a topic. So, if we were doing something, on like, energy conservation, we'd like, we put down three words that come to mind when you think of energy conservation. Yeah, and then everyone in the class can see that and use those words too.

> "As the students completed the tasks during lockdown, they were set up to be completed either individually or in a group. The majority of students completed their project individually. This was a class decision.

> And they would have come up with the success criteria themselves, with their role play and the talking heads thing, they came up, we'll do this topic individual, we'll do task, cycle 2, task 2, with the climate change we'll do more group work with that." (Teacher 2)

Group work was assigned with collaboration and communication skills in focus. Students discussed and shared their workload for the tasks. Students shared research ideas and keywords in individual tasks too by discussions in breakout rooms if their topic linked to keywords or research shared by other students. The students were actively involved in every session since they had a choice to work individually or in a group to begin with and had freedom to choose a topic that aligned with the task outline. They had discussions on planning, feedback from the teacher if desired at any stage of the task and clear success criteria. They also discussed their work for other students to analyse and pick ideas from. The students noted to have gathered ideas from each other and discussed their plans for the task. The breakout room sessions and WhatsApp messaging appear to have been beneficial for students to reflect on their own task and give feedback to their classmates. Sharing of research and draft ideas appears to be common classroom practice:

> "If they found anything that would kind of link to your one, if what you were doing then I usually use it. And also, when we were in the breakout rooms and if anyone had any good ideas, and I would be like, 'that's handy, going to use that one'. Or sometimes in class, they would be asking questions if this is a good idea or not. And then if I don't have that time, I end up using it as well."

The tasks were mainly completed at home, during lockdown but during online classes, students discussed progress in the breakout rooms. Students mainly had their own ideas for the task with few of them having common themes around the topic. A few of them chose to work in a group and communicated on the planning. Most students did not feel the need to explain the task to each other but they did discuss their own plans for the individual tasks in front of the class online. The tasks were sequentially divided and were provided to the students at the beginning. There were also no notable difficulties and disagreements:

> "There's no kind of conflict in any shape or form like that, it was fine. No resistance from anyone at all, which is perfect."

From the interviews, it can be seen that the students used the success criteria as almost a "checklist" for completing the task. Students commented that they could assess the level of their work based on the criteria and expected learning outcomes. According to the interview, students were well aware of the STEM skills they were expected to acquire and demonstrate through the exercise. The assessment was individual and the learning outcomes were consistent with the intentions and clearly articulated.

3.1.3. Challenges in digital assessment

3.1.3.1. What are the main difficulties?

There were a few significant challenges faced when conducting digital assessment. One of the major challenges would be the use of new digital assessment tools necessitated by the remote learning environment. Teachers had to spend time to be familiar with tools and choose what suited best for their lesson plans. Teachers also had to make provisions for guiding students on how to use the tools, in most cases remotely or in anticipation of another lockdown.

One of the teachers also ran into difficulties when registering the primary school students on a digital platform as the students needed their own email addresses before they would be able to use the tool. The children were aged below 13 years of age and thus not eligible for personal email addresses. The teacher then had to create email addresses for them to use. In essence, the teacher's workload increased significantly as they had to make sure every student had access to an email account and password before the start of the session.

In cases where teachers chose a particular tool like Mentimeter, the students would respond to a topic by entering keywords and answers in a common space. The answers were anonymous and the teacher could not single out a student for individual feedback.

> "Just to show you one of the problems with doing it online. See this here? So what will I use to measure the garden space? So, I wanted them to say trundle wheel, but you've got all sorts of things here. One of them says willow, so someone didn't even read it there. So, I can't catch it, because I'm not doing it with them, do you know that way?" (Teacher 1)

However, the students were in agreement that the anonymity of the tool made them feel more secure in answering the questions without fear of getting them wrong. The teacher would go through the answers and give general feedback for all students at the end of the exercise following a discussion of keywords and answers submitted by the class. There were general technology related issues with sharing of iPads in the classroom. One of the students admitted to "hogging the iPad" since their partner was not very enthusiastic about the task. The students were also in separate pods due to COVID-19 guidelines that isolated them from collaborating and sharing resources with other students outside of their shared space. One of the pilot school teachers stated that it was difficult to keep track of some students due to their frequent absences in part due to sharing of technology at home and no proper Wi-Fi access. This raises another challenging aspect of using technology: digital poverty and access. Students may not always have access to devices and technology needed for remote learning. Schools often do not have sufficient funding for efficient digital assessment support. Teachers also tend to adopt tools that are freely available for use and would not likely go for expensive versions even if they provide advanced features. Although these issues are centered around remote learning, it is important to note that use of digital devices and assessment tools is subject to availability of resources and access to supporting environments.

3.1.3.2. PROPOSALS AND RECOMMENDATIONS FROM THE AGENTS INVOLVED

Mentors advised that the digital tool selection is critical. It is important that their usage is considered and evaluated. Teachers should not select technology, just for technology's sake.

Teachers advised that preparation was vital. Students needed to be trained on how to use the technology, and all prerequisites and requirements for using the software had to be known in advance, such as students needing to have an email address.

Students have to be taught on how to give written peer feedback online, for example a positive point and recommendation.

CHAPTER 4. CONCLUSIONS AND PROPOSALS

This chapter is concerned with deriving conclusions from the data discussed above. It is organised around six questions. Each question is answered individually.

How might digital assessment practices support the development of STEM competences? How and with which digital assessment methodologies and tools can we improve STEM teaching and learning processes?

The many tasks and activities used by the case study schools revolved around the following planned STEM Competences: Problem-Solving, Innovation and Creativity, Communication, Collaboration and Disciplinary competences. The FaSMEd initiative, sponsored by the European Commission identified three ways technology can be integrated into the formative assessment process. They are as follows 1) "Sending and Displaying", actions that promote communication between students and also between students and teachers. 2) "Processing and Analysing", actions where technology facilitates the analysis of data related to assessment 3) "Providing an Interactive Environment", actions that allow students to work collaboratively or individually to investigate or engage with content (Reynold *et al*, 2020). These functionalities can be integrated into the following digital assessment practices: sharing learning outcomes/ clarifying success criteria, elicit evidence of learning through questioning/classroom discussions, giving and using feedback, peer/self-assessments (Reynolds *et al.*, 2021). These digital assessment practices when integrated with the functionality of digital tools were shown to support the development of STEM competences in this study. The following section discusses each digital assessment practice in turn and how it supported the development of STEM competences in the ATS STEM project in Ireland.

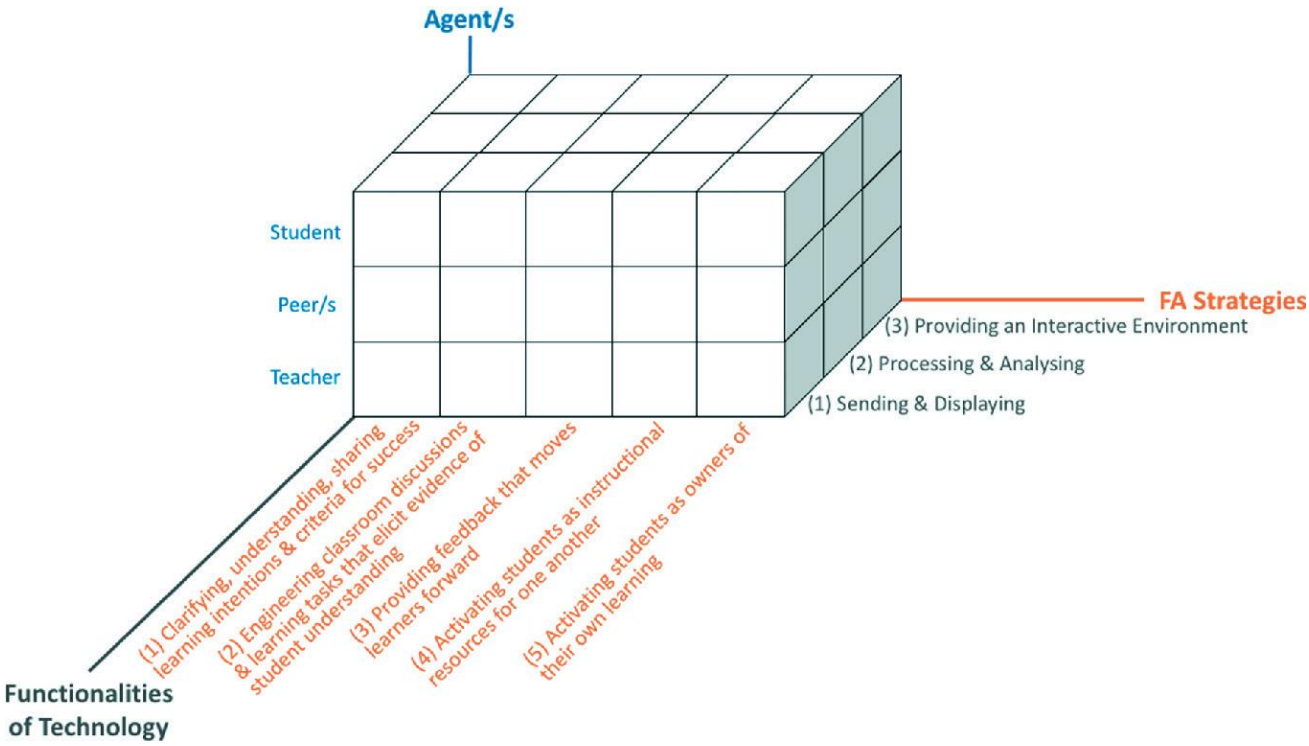


Figure 4.1 The FaSMEd Model for Technology Enhanced Formative Assessment (Reproduced from European Commission, 2016, p.5)

Sharing Learning Outcomes/Clarifying Success Criteria.

Students need to be cognizant of their learning outcomes and their subsequent success criteria to successfully reach their learning goal. This knowledge was shown to aid students' problem solving, with students articulating that they were

aware of what they had to do. During this project, learning outcomes were displayed using digital devices and applications. In particular, Powerpoint allowed Teacher 1 to easily bring up the learning outcomes at the start of each class and leave them on the board while students worked. In Case Study School 2, learning outcomes were permanently shared on the online platform for students to refer to as they worked. Thus technology assisted with "Problem-Solving" and "Communication".

Questioning/classroom Discussions

Questioning and classroom discussion was shown to aid "Problem-solving" and "Collaboration". Both case study schools used Mentimeter to facilitate questioning and classroom discussion. In Case School 2, it was reported how the questions posed by Mentimeter facilitated students' discussion on keywords to help with their research topic. Students brainstormed their answers first, and then once submitted to Mentimeter got to see answers by other students. This allowed all students to collaborate together. 61% of students (School 2) reported in a survey to their teacher that they felt the technology they used to complete their tasks improved their problem solving skills, and 76% felt it impacted their Communication Skills.

Peer Assessment: Activating Students as Instructional Resources for one another.

Wanner and Palmer (2018) highlight how peer assessment is effective for students improving their work, however they stress that students need training in how to give feedback. During lockdown, the online digital classroom in School 2 used the following tools from MS Teams, notebook, whiteboard and breakout rooms. These tools facilitated students' oral assessment of each other's work online. The teacher reported no conflicts or difficulties with the students during this process. However, two pilot schools reported that when peer assessment took on the form of online written assessment, they had to establish rules and train the students in how to give and communicate appropriate and respectful responses. In this way, the practice of peer assessment can support the development of STEM Competence communication.

Self-Assessment

Self-Assessment using digital tools was shown to improve self-regulation. Students reported in School 1 how the Blooket quiz motivated them to improve their scores for the next test. Linked indirectly to self-assessment, is the STEM Competence 'Innovation and Creativity' (McLoughlin *et al*, 2020). The digital tool Book Creator is used for eBook creation, which in itself facilitates students' creativity. However, an indirect link with self-assessment was observed, as the tool allowed for work to be shared by the teacher to the class using her interactive board. Students reported how they were influenced by what others had done. During lockdown online evaluation materials or rubrics were shared online, which provide students with the means to self-assess their work. Students reported at interviews that they felt confident to grade their work. Finally, using the tools themselves can support the disciplinary competences in respect to digital literacy.

How and with which digital assessment methodologies and tools can we improve STEM teaching and learning processes?

Reynolds *et al.* (2020) summarise the following four teaching and learning processes as being important for building critical STEM skills: problem and research-based learning, enquiry based learning, collaborative learning and mobile learning. Findings from this study highlight how the digital assessment methodologies and tools used by participating schools incorporate components of these learning processes. As stated earlier, digital assessment methodologies can be understood as the five strategies proposed by the ATS Framework. They are sharing learning outcomes/ clarifying success criteria, elicit evidence of learning through questioning/classroom discussions, giving and using feedback, and peer/self-assessments.

Padlet and PowerPoint support problem based learning, as they provide a mechanism (through their functionality of sending/displaying) to communicate to students learning outcomes and success criteria. If these outcomes are stored in a virtual classroom they will be available 24/7 for students.

Mentimeter and MS Teams' breakouts rooms and online whiteboard, support inquiry based learning (through their functionality of sending/displaying) as they facilitate discussion and questioning. In this study the Mentimeter communication was one way, in that it was teacher to student, but there is no reason why a student could not create his own Mentimeter questions. Mentimeter was used by the case study schools both synchronously and asynchronously (during lockdown). The Google classroom and MS Teams was also used by teachers to share knowledge with their students in the form of slides, documents and voice notes during lockdown.

Mentimeter was also instrumental in ensuring all students collaborated when answering a question. The digital tool Blooket, also ensured student collaboration, however this was due to how the tool was used, rather than the tool itself (as questions are answered individually). Students shared devices, and thus collectively answered the questions in pairs. This same premise can be applied with Book Creator as students worked collaboratively when using this tool, as they shared iPads. Mobile Learning is dependent on a digital device, and thus all the above mentioned tools can be accessed anywhere/any time.

Kahoot and Blooklet, (through the mechanism of analysing and processing) enabled both students and teachers to elicit evidence of their learning, and for both students and teachers to decide on what actions to take based on same. One Note accessed through MS Teams allowed students to upload their assignments and receive digital feedback from their teacher.

Why apply digital assessment in the development of STEM projects? What and how does it contribute to STEM teaching and learning processes?

The previous sections in this chapter highlighted how digital assessment methodologies supported the development of STEM competences and improved STEM teaching and learning. To avoid repetition, this section is concerned with elements not discussed in these answers such as student and teacher perspectives and peer learning.

Students in this study reported how much they liked the digital assessment tools. The primary students in case study school 1 highlighted how they found Blooket fun and engaging. They specifically liked the fact that the quiz could be incorporated into different games, thus allowing the assessment tool to be more than a multiple choice test. Students did not feel that they were being assessed. They were having fun learning.

Digital Assessment also incorporates tools that are multifunctional. Blooket allowed for both sending and displaying of information, but also processing and analysing data, as it produced a leader board, and indicated per question how many correct or incorrect answers. The students also received immediate feedback to their questions. When asked, students stated this was their preferred digital tool. Similarly, Book Creator, a tool used for creating eBooks not only allowed the "drop in" of text, sound, videos and annotation, but also facilitated self-assessment indirectly as students were able to view other students work. In case study School 2, 46% of students indicated how they found digital feedback the most useful, with the other 54% indicating that they found a mixture of verbal, copy book and digital feedback the most useful.

Digital Assessment through the use of its tools facilitated peer learning. In School 1 students' designs were shared on Padlet and Mentimeter which facilitated peer learning and student self-assessment. The multifunctional use of Book Creator allowed students' work to be shared on the teacher's interactive whiteboard; students reported that they were influenced by other's work. Book Creator was also shown to integrate different subjects such as art, English as well as Science. With Teacher 1 reporting how this tool helped with classroom management as she could observe on the one screen, what work the students were doing.

What and how does it contribute to STEM teaching and learning processes?

Digital Assessment contributes to STEM learning and teaching as it provides a vehicle for feedback, for collaboration of all students, questioning, discussion, and it elicits evidence of learning. The advantages of digital assessment practices as highlighted in ATS STEM Report #3 'Digital Formative Assessment of Transversal Skills In STEM' are the provision of feedback in a timelier manner; the assessment of hard to measure constructs and processes that were previously inaccessible; the inclusion of new item types capable of providing more nuanced information about learning; automation of the feedback process; access for students with disabilities; greater opportunities for student collaboration. Keeping these favourable benefits it should be noted that digital assessment practices should be centered around improving student learning as an end goal.

Digital assessment was used by Teacher 1 to establish "planned – for interaction" assessment, in that it allowed for the teacher to evaluate student's current understanding of a topic, and discuss the answers or take action on the same (Shavelson *et al,* 2008). Students had the confidence of knowing they can answer without fear of failure as their contributions are anonymous. This method also allowed for immediate input to class discussion as well as providing immediate feedback to students as they could establish if others had similar answers to them, if their answer was correct. It also helps them learn new answers. It was a tool used for Assessment for Learning. Similarly, Teacher 2 facilitated peer assessment by allowing students to share their work digitally followed by discussion in breakout rooms. Students communicated through MS Teams, Zoom and WhatsApp primarily since most of the assigned work was done at home during lockdown. Mentimeter was used to gather keywords on the chosen topic which allowed students to share ideas and support each other. As mentioned above, Teacher 2 surveyed students' learning process and student engagement with digital assessment tools. Teacher 2 stated:

> "It's good to get feedback from the children because it's their learning and giving them their voice and leadership in it is vital. Because like you know with changes in technology and teaching and learning is pretty changed. It's their futures and them being actively involved like you know and then taking it just, it's more meaningful."

It should be noted that digital assessment practices have generally been well received amidst the COVID-19 circumstances and proven vital in terms of remote teaching and learning.

What are the challenges to using digital assessment strategies in STEM learning?

The challenges observed with using digital assessment strategies in STEM learning, are similar to those already documented for challenges in digital assessment. The first challenge is in relation to the availability of devices, as digital assessment strategies rely on digital devices to implement their strategies. Especially at primary level, not all students have digital devices, or email addresses. In case study School 1, iPads were shared throughout the school, so the teacher needed to book in advance their usage. Due to COVID-19, the iPads had to be cleaned after each use, and the teacher had to ensure that students got the same iPad, for both lessons, as images for their books were stored on the iPad. The teacher had to create temporary email accounts for many students, so that they could use the Book Creator application. For the students, who had an email account, parental permissions on their accounts prevented their usage with the app, and parents were unable to resolve this. The teacher had taken the time to troubleshoot the email issues before the lesson, and to have workarounds already in place. The second challenge is in relation to the learning curve of using the tools. Teacher 2 stated how his class had weekly lessons from September to December to show students how to use MS Teams. The school had anticipated, and was proved right that a level 5 lockdown was imminent, and prepared for such. With reference to devices used by students during COVID-19, one of the pilot teachers stated that he believed the majority of his students were using phones. He outlined the challenges with that, in how using a small device, his students had to log onto a google classroom, take a photograph, convert to pdf, upload it, find comments, view comments and then log on to a different Padlet, and put feedback up there. He outlined that this was just for his class. Other teachers may have been using different assessment tools. Another challenge highlighted with respect to the device was its usage. In case study school 1, the teacher had to have paper based peer assessments, as the students were using the devices at the time, and it would have been too difficult for them to keep leaving the Book Creator app, to submit a response to a digital peer assessment and then back to the app.

With reference to the strategies of evidence of learning and questioning/discussion, Teacher 1 pointed out how the anonymity of Mentimeter, while loved by the students, prevented the teacher from knowing the names of students who misunderstood the question, or needed more information.

2. Limitations of the study

In the general implementation of the project, it should be noted that all data gathered was under COVID-19 restrictions and guidelines. This meant that the usage of digital tools and platforms exponentially increased amidst the lockdown shift towards remote teaching and learning. The data gathered under unusual circumstances is biased towards the digital by default. While this works well for the amount of data gathered it also defeats the objective of testing digital assessment in normal classroom environments. Thus it is recommended that if possible the implementation of the project be carried out separately after schools settle into normalcy. The data gathered then would be the most realistic indicator of digital assessments in schools.

It should also be noted that due to COVID-19, this study was conducted under adverse conditions, with COVID-19 affecting all agents concerned with this project. Mentors reported that COVID-19 affected their relationship with the participating teachers. They did not meet face-to-face or interact socially, and thus were missing the connection that results from such meetings. The mentors felt that more emails would have been answered, if an initial connection had been made with initial face-to-face team training. COVID-19 affected teachers' interactions. This is especially applicable to second level teachers, where there are different subjects taught by different teachers. Teachers missed out on the support, and learning from other teachers, specifically regarding the integration of interdisciplinary content. Teachers reported that a lot of learning happens during social chats in the staff room.

COVID-19 affected the ATS STEM projects in schools. Many teachers' initial designs for their projects did not translate well to an online environment. Access to science labs were required. Teachers were forced to change their projects. Primary teachers in particular spoke about requests from parents to reduce the workload, and to concentrate on core subjects only. COVID-19 affected access to schools, even when lockdown restrictions were reduced, in March, many schools (specifically second level schools) did not allow non-teachers on campus.

3. Recommendations and proposals for the implementation of STEM and digital assessment projects in schools.

In the Irish context, the workshops by teacher mentors were crucial to understand the ATS STEM framework and application. The supporting material, especially the ATS STEM learning design cards developed by Kildare Education Centre and Dublin City University based on the ATS STEM Conceptual framework, were noted to be helpful for lesson planning and execution. Teachers also mentioned the ATS STEM framework and guidelines for developing the lesson plan improved their teaching experience. The teacher networking events were well received and it would be worth scheduling them in advance and running them in parallel with implementation phases. Networking events with teachers from other countries were valuable and not fully incorporated in the original study design of this project. Connecting teachers in this way has many parallels with the teacher team working in schools and student collaboration and will help realise solutions that have wider impact.

Students' access to devices at both home and schools has to be considered, specifically if students only have access to a phone. Preparation is key, devices have to be charged, all the requirements of an application have to be considered in advance, such as email access, student's knowledge of their passwords and internet access. Research at EU level has highlighted that schools across the region have varying levels of digital capability, both in terms of the tools and infrastructure available and teacher skills and competences in their usage (European Commission, 2019). The diverse picture of the levels of technology across and even within countries and regional schools is a practical issue when developing scalable and replicable European approaches and is borne out by this evaluation at micro-level i.e. teachers and students have varying access to tools and technologies both in school and at home.

Digital tool selection is important, teachers need to interrogate their need and use to ensure they tools are addressing the key components of formative assessment and allowing cultures of assessment literacy to build amongst students (Carless and Winstone, 2020) . Selecting tools that are multifunctional, and that consider both teachers and students' perspectives is recommended, as they reduce training, and facilitate the integration of many digital assessment strategies.

With reference to transversal skills STEM projects, specifically for primary students, the objectives are recommended to be detailed and specific. For both primary and secondary students, we recommend selecting real-world problems that have local context, and are interdisciplinary. Teachers reported that students were more engaged when the context was local. Primary students reported at the interview how they enjoyed the interdisciplinary aspect of the projects. In the Irish context, the interdisciplinary element is easier at the primary level, than secondary level. At second level, the ATS STEM framework can be used and incorporated into Irish Students CBA's as demonstrated in school 2 here.

At policy level, there is a need for structured support scaffolding digital assessment practices across Ireland. Thus awareness and consideration of the key challenges surrounding implementation of STEM projects and digital assessment in schools is vital to effective policy development. Moreover, the issues go beyond simple digital solutions. Best practices here included examples of outdoor learning using analogue tools and digital tools are highly interactive and engaging but also volatile and unreliable.

The importance of school spaces indoor and outdoor is highly important. As we highlighted student and teacher use of issues in their own locality for teaching is highly effective and the best example of this is in the school itself where students helped design a new garden. This allowed learners directly transform their environment via a pedagogy of student empowerment.

REFERENCES

Baïdak, N., Sicurella, A. and Matti Riiheläinen, J., (2020). The Structure of the European Education Systems, 2020/21: Schematic Diagrams. Eurydice--Facts and Figures. Education, Audiovisual and Culture Executive Agency, European Commission.

Carless, D., & Winstone, N. (2020). Teacher feedback literacy and its interplay with student feedback literacy. Teaching in Higher Education, 1-14.

Costello, E., Girme, P., McKnight, M., Brown, M., McLoughlin, E., & Kaya, S. (2020). Government Responses to the Challenge of STEM Education: Case Studies from Europe. ATS STEM Report #2. Dublin: Dublin City University. http://dx.doi.org/10.5281/zenodo.3673600

DES (2017) STEM Education Consultation Report 2017. Dublin.

Economou, A. (2018) ATS2020-Assessment of transversal skills: Reflections and policy recommendations on transversal skills development and assessment. Cyprus. Available at: http://www.ats2020.eu/images/documents/ATS2020-Reflections.pdf.

European Commission (2017) Ireland, Eurydice – European Commission. Available at: https://eacea.ec.europa.eu/national-policies/eurydice/content/ireland_en (Accessed: 28 July 2021)

European Commission. (2019). 2nd Survey of Schools: ICT in Education. Publications Office of the European Union, Luxembourg. http://dx.doi.org/10.2759/23401

Government of Ireland (1999) 'Irish Primary Curriculum'. The Stationary Office. Available at: https://www.curriculumonline.ie/getmedia/c4a88a62-7818-4bb2-bb18-4c4ad37bc255/PSEC_Introduction-to-Primary-Curriculum_Eng.pdf#page=47&zoom=100,0,0.

Hattie, J., & Timperley, H. (2007). The power of feedback. Review of Educational Research, 77(1), 81-112.

McLoughlin E., Butler., D., Kaya, S. and Costello, E. (2020). STEM Education in Schools: What Can We Learn from the Research? ATS STEM Report #1. Ireland: Dublin City University. http://dx.doi.org/10.5281/zenodo.3673728

NCCA (no date) Junior Cycle is changing, Curriculum. Available at: https://www.curriculumonline.ie/Junior-cycle/Junior-Cycle-is-changing/ (Accessed: 1 June 2021).

Reynolds, K., O'Leary, M., Brown, M. & Costello, E. (2020). Digital Formative Assessment of Transversal Skills in STEM: A Review of Underlying Principles and Best Practice. ATS STEM Report #3. Dublin: Dublin City University. http://dx.doi.org/10.5281/zenodo.3673365

Szendey, O., O'Leary, M., Scully, C., Brown, M., & Costello, E. (2020*). Virtual Learning Environments and Digital Tools for Implementing Formative Assessment of Transversal Skills in STEM*. ATS STEM Report #4. Dublin: Dublin City University. http://dx.doi.org/10.5281/zenodo.3674786

Shavelson, R.J. et al. (2008) 'On the Impact of Curriculum-Embedded Formative Assessment on Learning: A Collaboration between Curriculum and Assessment Developers', Applied Measurement in Education, 21(4), pp. 295–314. doi:10.1080/08957340802347647.

Wanner, T. and Palmer, E. (2018) 'Formative self-and peer assessment for improved student learning: the crucial factors of design, teacher participation and feedback', Assessment & Evaluation in Higher Education, 43(7), pp. 1032–1047. doi:10.1080/02602938.2018.1427698.