



Immersive STEM Learning Experiences to Shape Shared Futures

Insights from the
STEM Teacher
Internship
Programme



**STEM Teacher
Internship Programme**

A DUBLIN CITY UNIVERSITY INITIATIVE TO
INSPIRE INNOVATIVE LEARNING

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Authors

Dr Mairéad Hurley – Programme Manager, STEM Teacher Internship (STInt) Programme, Centre for the Advancement of STEM Teaching and Learning (CASTeL), Dublin City University (DCU)

Professor Deirdre Butler – School of STEM Education, Innovation and Global Studies, DCU and Programme Director, STInt Programme, CASTeL, DCU

Associate Professor Eilish McLoughlin – School of Physical Sciences, DCU and Programme Director, STInt Programme, CASTeL, DCU

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Mr Bernard Capraro – Research Manager, Silicon Technology, Intel Research and Development Ireland Ltd.

Ms Gillian Harford – Country Executive, 30% Club Ireland

Dr Shalini Hollingum – Product Manager, Accenture, STInt Programme Industry Liaison

Professor Anne Looney – Executive Dean, DCU Institute of Education

Mr Paul McCabe – Chief Operating Officer, VLE Therapeutics

Ms Claire McEvoy - STInt Programme Manager, CASTeL, DCU

Dr Jennifer McKenna, Intel R&D Ireland, STInt Programme Industry Liaison

Ms Paula Neary – Managing Director, Communications, Media and Technology, Accenture

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Executive Summary

This White Paper presents an ambitious vision for the type of education system required to prepare learners for the future. It contains a strong focus on integrated science, technology, engineering and mathematics (STEM) education, essential for developing the necessary competences to thrive in our complex, ever-changing world. Within such a holistic and equitable education system, these learners will be equipped to realise a planet with thriving and sustainable societies, economies and environment.

We posit that teachers are the catalyst to realising this vision and ensuring that effective, sustainable systematic change happens. However, they cannot do it alone and will need the support of a range of stakeholders and actors to create this effective learning ecosystem. Considering this and also the point that the most impactful moment to influence the teachers of the future is during their initial teacher education - when they are fully immersed in the processes and practices of active, situated learning - designing an intervention that focused on working with pre-service teachers seemed the logical

starting point. If these teachers are to design authentic learning experiences which integrate core STEM competences within real-world contexts, we believe it is essential that they have first hand experience in these contexts themselves. Only with such a rounded experience, will they be in a position to inspire truly innovative STEM learning in their classrooms. These ideas are what led to the development of the STEM Teacher Internship (STInt) Programme, which encapsulates clearly how building partnerships between teacher educators, student teachers and industry can play a part in shaping the shared futures of the next generation of Irish students.

However this is only the beginning, and in the process of working on the STInt Programme since 2016 we have come to realise with greater clarity that there are major challenges we still need to address within the wider ecosystem in realising our vision of designing innovative learning environments.

This White Paper argues that two major challenges are:

- Inequities in education broadly, and specifically issues of diversity, equity and inclusion in STEM education, which lead to inequities in STEM professions and careers.
- The need for consensus between research/higher education, policy and practice when it comes to STEM education, and the need for capacity-building measures to support teachers to deliver integrated STEM education.

We propose two recommendations for actions to address these challenges:

- 1 Build and deepen teachers' understanding of integrated STEM education through immersive professional experiences in real-world STEM contexts.
- 2 Develop and strengthen the connections across and between actors within the STEM learning ecosystem to improve learner outcomes.

Throughout this document, we present a number of “Spotlight on Practice” boxes – showcases of exemplary programmes, projects or approaches being developed and deployed in Ireland and internationally, which we believe have the potential to address these challenges and inform the proposed strategic actions.

These two recommendations are designed to act at different scales, from that of the individual teacher, to the regional and national systems level.



1 – Build and deepen teachers' understanding of integrated STEM education through immersive professional experiences in real-world STEM contexts

Teachers have great potential to influence educational equity broadly as well as in particular in STEM. They may foster students' STEM interest and identities through inspiring classroom practices, as well as providing access to role models and information about the diverse careers that exist within STEM industries.

This White Paper provides an overview of a successful collaborative partnership to strengthen teachers' capacity for integrated STEM education: the STInt Programme. Evidence from the first six years of the programme shows that internships in STEM roles during pre-service teacher education can significantly impact teachers' understanding of STEM and STEM careers, and influence their future classroom practice.

The STInt Programme has expanded from five Dublin City University (DCU) pre-service teachers undertaking internships in one host organisation (Accenture) in 2016, to 45 students from DCU, Maynooth University and University College Dublin undertaking internships in 25 host organisations in 2021. The next step at this critical juncture is to expand the STInt Programme to a national initiative, offering STEM internship opportunities to all pre-service teachers of STEM subjects at primary and post-primary levels. Investment in teacher education at such a scale will, in the long-term, translate to improved STEM education in Irish schools, increased STEM literacy and capacity in Irish society, and increased diversity, equity and inclusion in STEM at all levels.

2 – Develop and strengthen the connections across and between actors within the STEM learning ecosystem, to improve learner outcomes.

STEM education can be improved if supported through an “ecosystem” model, in which multiple stakeholders including formal and non-formal educators, research and higher education, policymakers, business and industry, families and young people themselves work together towards shared educational and societal goals.

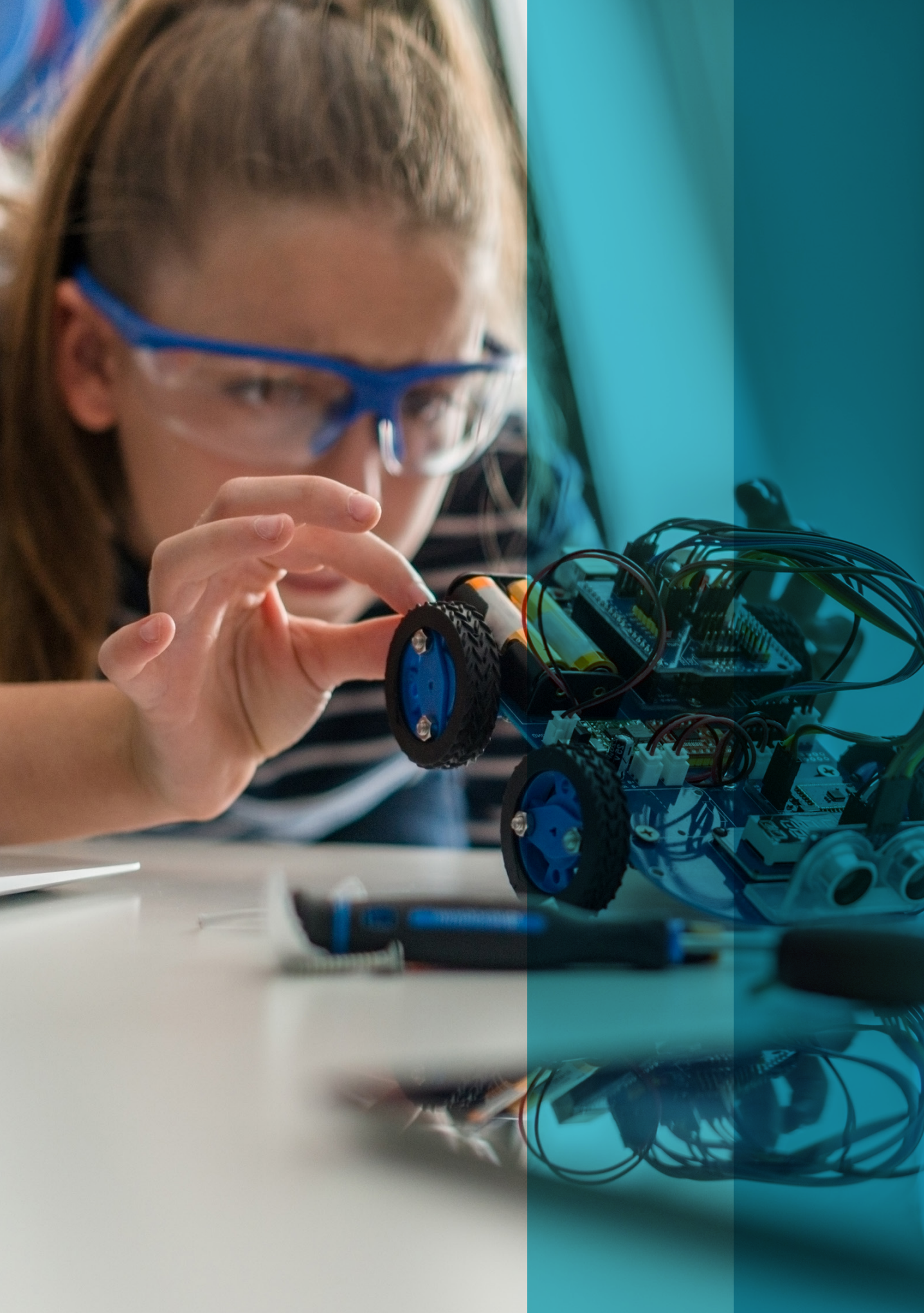
We suggest that the partnerships formed between higher education, business and industry, and teachers that have been developed by the STInt Programme at DCU provide a valuable basis for a strong Irish STEM Learning Ecosystem, and recommend further investment in this network.

This White Paper urges collaboration between policymakers, STEM businesses and industries, and higher education, to realise this vision of the education system of the future. It is a call for long-term policy investment in the infrastructure required to transform the STInt Programme from a fully functioning pilot programme serving three universities, to a national programme offered to each and every teacher who will play a part in shaping the shared futures of the next generation of Irish students.



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A person with a beard is shown from the chest up, wearing a dark shirt. They are holding a pen and writing in a notebook. The image is overlaid with a semi-transparent blue filter. The text is white and positioned on the left side of the image.

Rethinking Education

Our world and educational systems are constantly evolving to address new challenges and demands faced by society. Education must prepare young people to innovate and to address problems that were not even imagined at the dawn of the 21st Century.

Rethinking Education

Our world and educational systems are constantly evolving to address new challenges and demands faced by society. Education must prepare young people to innovate and to address problems that were not even imagined at the dawn of the 21st Century. We live in a connected society, and we learn at unexpected times and in a multitude of places - beyond the walls and timetable of a school.

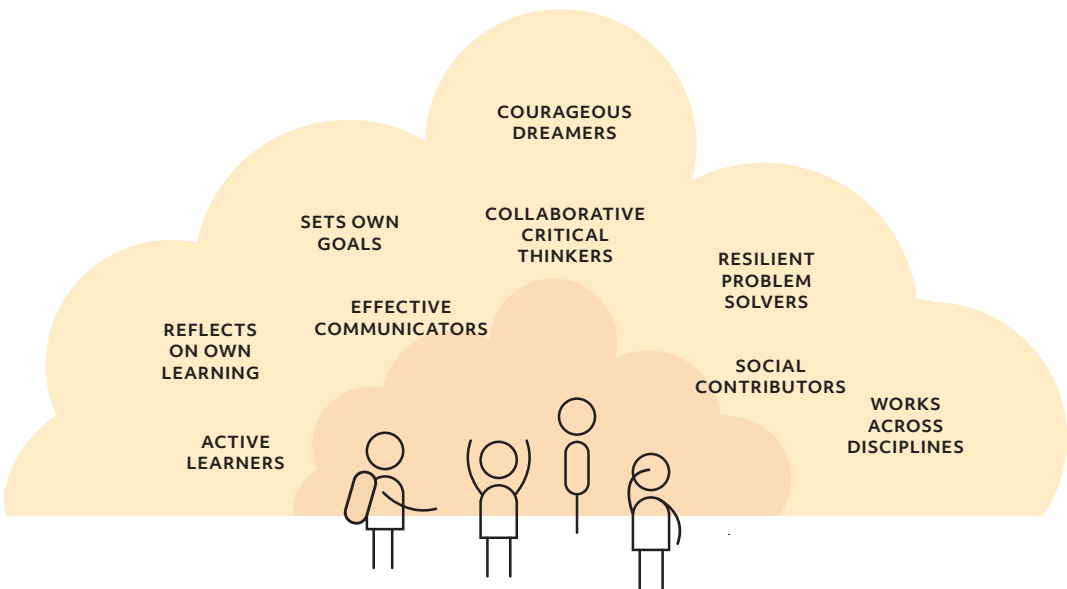
Due to economic, environmental and societal transformations, and the impact of digital technology, the needs of society have changed. Current educational models need to be critically examined to determine whether they are actually addressing the needs of our future generations, or if we need to reconceptualise new models.

Proposed features for educational models of the future

Educational models should...	Why?
Focus on competences for the future	<p>Education needs to prepare our young people for the future by developing the competences they will need to navigate a complex, connected and rapidly-changing world¹. Future generations will need to:</p> <ul style="list-style-type: none">– Be curious, creative and open to learning.– Think critically and communicate clearly.– Empathetically collaborate across boundaries and borders, with people who are different from themselves.– Use technology effectively and ethically to support their living and learning. <p>Therefore, their education must place an emphasis on developing transversal competences alongside disciplinary knowledge and skills.</p>
Connect across people, places, time and discipline	<p>Learning happens across an array of settings and over the entire course of someone's life. The prior knowledge someone brings to an educational setting depends strongly on their life experiences, family background and personal interests. A one-size-fits-all approach to learning does not leverage these rich funds of knowledge that each person holds. We must promote a 'connected learning'² approach in our future educational models that incorporates individual interest as well as social support to realise resilient, effective and adaptive learning.</p> <p>We are living in an increasingly connected global society, where siloed approaches to learning no longer serve our needs - 'wicked problems'³ such as climate change or social inequality are messy and entangled, and need to be tackled using transdisciplinary approaches which centre empathy and social justice.</p>
Promote Inclusive and Equitable Education	<p>Education is one of the UN's 17 Sustainable Development Goals.⁴ Educational models of the future must promote equity of access to quality education for all people, regardless of gender, disability or other disadvantage. Equitable education is key to a sustainable future.</p>

Table 1: Proposed features for educational models of the future

Figure 1: Learners of the Future



**EQUIPPED WITH A MORAL COMPASS, AND A DESIRE TO
WORK IN CO-AGENCY WITH OTHERS TOWARDS WELL-BEING,
FOR THEMSELVES, FOR OTHERS, AND FOR THE PLANET**

In order to control and shape the world around them rather than being shaped by the agendas of others, future generations need to be empowered active global citizens with critical agency to realise a more inclusive and sustainable future for our world.

Covid-19 and the climate crisis are reminders to us that the most pressing global challenges of our time, and of the future, must be tackled at scale through science, technology, engineering and mathematics (STEM) innovation as well as international cooperation. Consequently, it is imperative

that every child has access to high-quality STEM learning experiences as part of their education. Whether or not they progress to higher education or careers in STEM, through STEM education they will become aware of and can engage with STEM issues in their everyday lives.

STEM education has tended to focus on the study of the individual disciplines of science, technology, engineering and mathematics, but the focus should be on the integration of these disciplines, applied to develop solutions to problems in

real-world contexts. In today's world, a significant responsibility of teachers at all educational levels, from early-childhood to school leaving age, is to promote a STEM mindset. A young person with a STEM mindset is a curious and creative critical thinker open to experimentation, and is resilient, learning from mistakes and setbacks. The competences developed through STEM education are invaluable not just for successful careers in STEM, but also across a wide range of societal contexts.

What is the Purpose of STEM Education?

Civic Participation

A high-quality STEM education is essential for all students, not solely those interested in pursuing further studies or careers in STEM. The challenges facing our planet are increasingly related to STEM: climate change, public health, aging populations, big data, artificial intelligence, food and water security to name but a few. Citizens need to be able to interpret data and use evidence-based reasoning to make well-informed decisions about issues of global significance affecting the future of humanity.

Careers and the Digital Economy

In order to meet the demands of our ever changing and complex society, to maintain the level of progress of research and innovation, and to provide the technological underpinning required by all sectors, there is a constant demand for highly-qualified and skilled workers. In particular, there is a need for a more digitally literate society.

The need for more digitally literate graduates relates in some part to our global transition to a “digital economy” - the shift towards the reliance of countries on information and communication technologies and the internet to meet their public policy objectives⁵. According to the ‘*Digital Economy and Society Index Report 2019: Integration of Digital Technology*’⁶, Ireland is the leading EU country for

integration of technology in business, and records the highest growth in digital public services.

The Future of Jobs

Due to economic, environmental and societal transformations, and the impact of digital technology, humans crucially need the capacity to learn and adapt, as the skills and competences needed to thrive in our world continually change at a rapid pace. Jobs of the future, and not just those in STEM industries, will require higher order skills and competences. According to the ‘The Future of Jobs Report 2020’ from the World Economic Forum, analytical thinking and innovation, active learning, and complex problem-solving are top of this list in the coming years. These competences can be nurtured and developed through high-quality STEM education, which promotes curiosity, creativity and collaboration.

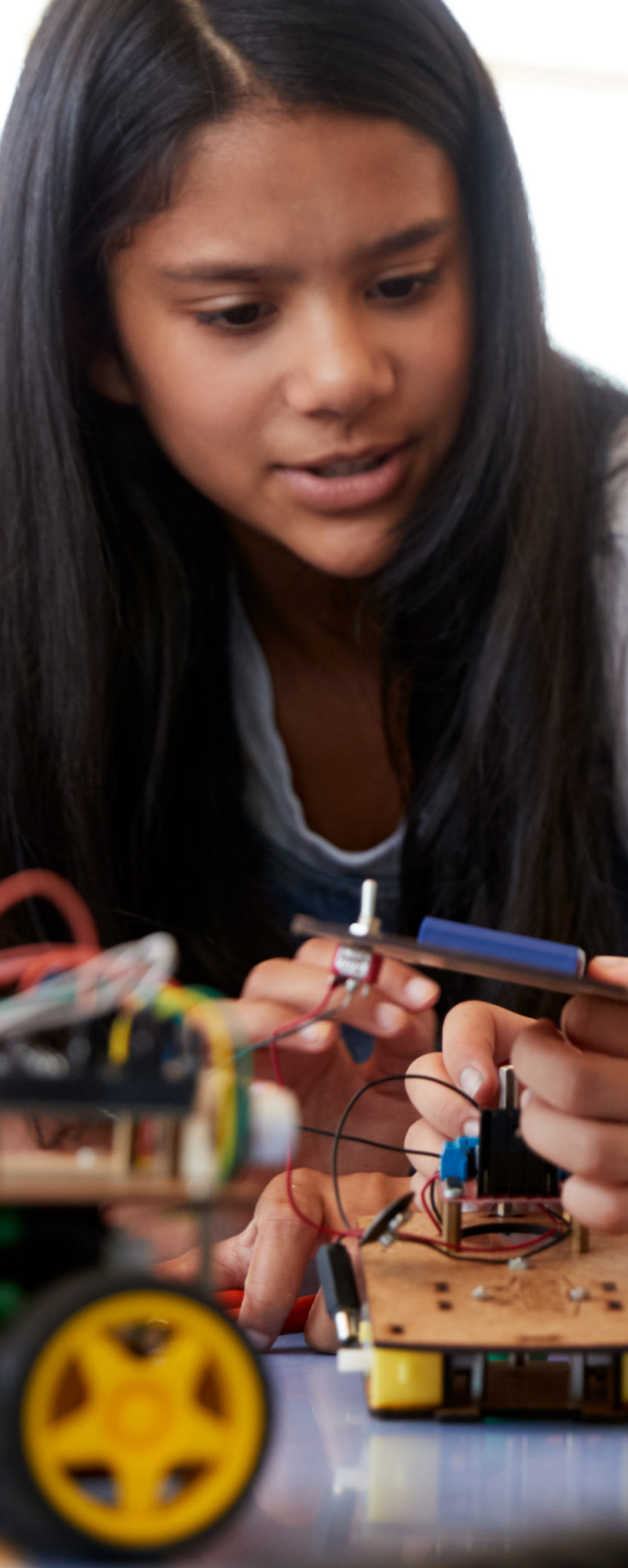
According to situated learning theory⁷, learning happens through participation in a community of practice, such as within a workplace - an apprenticeship is an example of situated learning. For teachers to prepare students for the jobs of the future, their own situated learning of these skills within the context they may one day be applied by their students is a crucial part of their own education.

A 2018 STEM Skills Indicator study estimated that the shortage in STEM-skilled workforce is costing UK industry £1.5bn per year.

The Future of Jobs Report 2020

Published by the World Economic Forum ⁸, this report finds that the pace of technology adoption is expected to remain unabated and may accelerate in some areas. However, the growth potential due to the adoption of new technology is not realised in some industries due to high skills gaps of the available workforce. The biggest increase in demand in job roles is for data analysts/scientists, AI and Machine Learning specialists, and Big Data specialists, while demand for data entry clerks, accountants, HR specialists and construction labourers is declining. To address this shift in the types of jobs in demand in the future, the top 10 skills needed by the workforce by 2025, according to the 291 companies surveyed for this report, will be the following:

- Analytical thinking and innovation
- Active learning and learning strategies
- Complex problem solving
- Critical thinking and analysis
- Creativity, originality and initiative
- Leadership and social influence
- Technology use, monitoring and control
- Technology design and programming
- Resilience, stress tolerance and flexibility
- Reasoning, problem-solving and ideation



The background of the slide features a photograph of several students in a classroom setting, looking down at their work. The image is heavily overlaid with a semi-transparent blue color, which serves as a backdrop for the white text. The students are wearing various clothing, including a striped shirt and a blue shirt.

Challenge #1 Equity, Diversity and Inclusion in STEM Education

“Equity does not mean that all students obtain equal education outcomes, but rather that differences in students’ outcomes are unrelated to their background or to economic and social circumstances over which students have no control.”

OECD: Equity in Education: Breaking
Down Barriers to Social Mobility
(2018), p. 13

Challenge #1

Equity, Diversity and Inclusion in STEM Education

Research demonstrates that the disparities in educational attainment that are related to socio-economic disadvantage appear as early as 10 years of age, and widen throughout a student's life.⁹

According to the 2018 OECD report "Equity in Education: Breaking Down Barriers to Social Mobility", teachers can be instrumental in supporting students facing educational disadvantage: "teachers and schools can foster students' well-being and create a positive learning environment for all students by emphasising the importance of persistence, investing effort and using appropriate learning strategies, and by encouraging students to support each other, such as through peer-mentoring programmes." The role of the teacher is paramount in supporting youth to reach their potential, to develop resilience, and to feel supported as part of a learning community. Teachers can support their students by drawing from the funds of knowledge they have gained throughout their own learning journeys.

It is well documented that teacher preparation and teacher quality are by far the strongest correlate of student achievement, even after controlling for factors such as students' language and poverty status.¹⁰ **Investment in quality teacher education is one of the most effective ways to support young people facing educational disadvantage.**

Gender and STEM in Ireland

Multiple sources have confirmed that Ireland has a gender inequity issue in relation to STEM, in terms of the number of females opting to continue STEM studies to Leaving Certificate level in post-primary education, and the percentage of higher education STEM graduates, in particular in technology, engineering, mathematics and physical sciences. There are also issues around the limited availability of these subjects in all-female post-primary schools¹¹.

According to recent research carried out by I Wish (2021)¹², when it comes to subject choices for Leaving Certificate, teachers are the primary influence on 69% of the 2449 teenage girls surveyed, ahead of family, role models or peers. However, this may not translate to influence on career choices - Accenture in Ireland's 2019 research¹³ revealed that only 32% of the 103 female students surveyed sought career advice from teachers, compared to 70% from mothers. Meanwhile, 66% of the 150 parents surveyed by Accenture in Ireland for this study feel that students are not getting enough info on careers in school.

The Irish government has responded by making gender equity an underpinning principle in its 2017 - 2026 STEM policy¹⁴: "*STEM education should be for learners of all backgrounds, ability and gender*" (p. 9). However, a 2020 progress report on the implementation of the STEM policy¹⁵ recommends that "further work is required to ensure gender equity in STEM education" - mentioning that gender stereotyping, curriculum accessibility and resourcing are continuing contributing factors exacerbating the issue.

According to the '*Review of Literature to Identify a Set of Effective Interventions for Addressing Gender Balance in STEM in Early Years, Primary and Post-Primary Education Settings*'¹⁶, there is no single barrier to gender equity in STEM education, and interventions must address a range of stakeholders and settings, including learners, families, school and early-years settings, as well as wider society, to develop STEM capital¹⁷ through formal and informal education.

Spotlight on Practice #1

Improving Gender Balance (Ireland)

Researchers from Dublin City University's Centre for the Advancement of STEM Teaching and Learning in a strategic partnership with the Institute of Physics and Science Foundation Ireland implemented the Improving Gender Balance programme (2017-2019)¹⁸ with the objectives to:

- I Deepen science teachers' confidence and content knowledge for teaching physics.
- II Adopt a whole school approach to addressing unconscious bias and gender stereotyping and build confidence and resilience for students, particularly girls, to continue with physics.
- III Increase awareness of STEM and careers in STEM.

A three strand approach to address these objectives was implemented over two phases. In Phase I, seven secondary schools were recruited to partner in this programme for a two year period, with a further twenty-one schools joining the programme for Phase II, which lasted five months. The impact of the programme was evaluated using qualitative and quantitative data collected and analysed by both internal and external evaluators.

The findings of this programme identified nine essential steps for achieving equity and inclusion in STEM education. These nine steps present a robust framework for national implementation of the Improving Gender Balance in Ireland programme, to support teachers and students of physics in all Irish second level schools.

- 1 Commitment of School Management and Leaders
- 2 Collaborating between Key Stakeholders
- 3 Bringing Together Research and Practice
- 4 Professional Learning Opportunities
- 5 Raising Awareness of Unconscious Bias
- 6 Deepening Confidence and Competence in the Teaching and Learning of Physics
- 7 Building Student Resilience
- 8 Active Learning in Physics
- 9 Challenging Barriers to Inclusion.

The role of the teacher is paramount in supporting youth to reach their potential, to develop resilience, and to feel supported as part of a learning community.

Equity in STEM cannot be considered without accounting for the wider questions of equity in education, and in society more broadly. An inquiry on equity in STEM Education in the UK¹⁹ was published in 2020, generated through a review of evidence and expert consultations. One of the key findings is that “inequity cannot just be seen through the lens of gender, economic disadvantage or ethnicity” - it is a question of social justice broadly. This report also finds that strengthening teacher capacity can lead to positive

educational outcomes for young people.

Diversity in STEM is directly related to equity and inclusion in STEM education. Decades of research have demonstrated that women are under-represented in STEM higher education and careers, in Ireland and worldwide²⁰. Under-representation or discrimination in STEM has also been revealed for certain ethnic and racial groups, as well as based on socio-economic background, disability, gender identity or sexual preference²¹. Equality is

not simply a human rights issue. From a science and innovation standpoint, creativity is known to flourish when there is greater diversity in teams, as multiple perspectives boost problem solving and reduce potential bias.

To increase diversity in STEM, there is a need for equity of access to high-quality STEM education in schools at all educational levels from early childhood onwards, as well as opportunities to engage with STEM outside of school.

Spotlight on Practice #2

IGGIES: Irish Girl Guides Innovatively Engaging in STEM (Ireland)

Initial funding from Science Foundation Ireland for the IGGIES project (2016-2018)²² enabled researchers from Dublin City University's Centre for the Advancement of STEM Teaching and Learning to engage in a substantial capacity building programme with the Irish Girl Guides (IGG) - the largest female youth organisation in Ireland (membership 12,000+). Working with Brownies (girls aged 7-10 years) and their leaders, the project focused on the development of solutions to the real world problem of water conservation. Each team designed, built and programmed an autonomous motorised LEGO model incorporating a range of sensors and motors, designed a poster with diagrams of the solution they presented and the feasibility of executing the project. All the projects were shared by the Brownies with their families and invited guests including researchers at two showcase events in Dublin City University St Patrick's Campus. In addition, funding from the HEA from 2018 to date has enabled the project team to design and facilitate five, week long face-to-face robotics camps (three in Dublin

and one in both Cork and Cavan) as well as a series of online national camps during Covid lockdown (200+ Guides). Each camp focuses on real world problems related to the UN Sustainable goals and the girls design, develop and share their solutions at showcase events. Several teams have also successfully participated in regional and national FIRST Lego League tournaments and two teams qualified for the virtual UK and Ireland finals (2021) with one of the teams securing second place for their innovation project.

So starting initially with 400+ Brownies and their Leaders, this relationship with IGG has extended to programme developments across all age ranges from Ladybirds (aged 5-7 years), Brownies (aged 7-10 years), Girl Guides (11-15) Senior Branch (16+) as well as Leaders within the organisation. In addition, the IGG leveraged the learning developed during these initiatives to include STEM in a box activities, as well as a range of articles on the importance of STEM in a specially produced publication for their international Octagon camp (2021) with participation from 1000+ girls in 10 countries globally.

To increase diversity in STEM, there is a need for equity of access to high-quality STEM education in schools at all educational levels from early childhood onwards, as well as opportunities to engage with STEM outside of school.

Spotlight on Practice #3


Learning in Places (USA)

The University of Washington Bothell Goodlad Institute for Educational Renewal, Northwestern University School of Education and Social Policy, Tilth Alliance and Seattle Public Schools, along with educators, families, and community actors are partnering on the Learning in Places project²³ to co-design innovative research and practice that cultivates equitable, culturally based, socio-ecological systems learning and sustainable decision-making. These culturally- and community-relevant science learning opportunities occur in outdoor places, including gardens, and are aimed at children in Kindergarten to 3rd grade along with their families.

This handy Practice Brief²⁴ outlines some of the key ways that frameworks and resources from the Learning in Places project can be used by educators and families to consciously engage in scientific sense-making in their local environment. This may include a neighbourhood walk, telling culturally-relevant stories related to the seasons, or collective decision-making to design an outdoor learning space.







Challenge #2 Towards Integrated STEM Education

As we prepare learners to live and work in a complex and connected society, it is becoming increasingly apparent that education should not be confined to single subject disciplines, and happen only within the school walls.

Challenge #2

Towards Integrated STEM Education

“.. a competency is more than just knowledge and skills. It involves the ability to meet complex demands, by drawing on and mobilising psychosocial resources (including skills and attitudes) in a particular context”

OECD: The Definition and Selection of Key Competencies (2005), p. 4

As we prepare learners to live and work in a complex and connected society, it is becoming increasingly apparent that education should not be confined to single subject disciplines, and happen only within the school walls, but rather reflect the entangled and dispersed nature of 'real-world' problems. It must also encompass learning in digital as well as physical spaces.

While educators, policy-makers and industry are in agreement on the importance of '21st Century' or 'transversal' skills for the learners of today

and the workforce of tomorrow, current knowledge-based curricula and high-stakes examinations do not assess many of these critical skills and dispositions. In order to address the need for citizens to possess higher-order skills, knowledge and competences, international education research indicates a shift towards purpose-driven quality curriculum frameworks in which learners tackle problems from a multi-disciplinary viewpoint, developing inter-related key competences and skills across subject boundaries²⁵.

Curricula of the future must be responsive, adaptable, and reflective of the local context, while striving towards a shared purpose for education - to be equitable, inclusive and sustainable, benefitting the individual as well as the global community.

Spotlight on Practice #4

OECD Learning Compass 2030 – education for an inclusive and sustainable future

The OECD has developed the Learning Compass 2030 - a responsive and evolving learning framework that “sets out an aspirational vision for the future of education”.

According to the OECD, “the compass is a tool students can use to orient themselves as they exercise their sense of purpose and responsibility while learning to influence the people, events and

circumstances around them for the better.”

Building on foundational knowledge, skills, values and attitudes to develop core competences, learners, in co-agency with their peers, schools and communities, will work in a cycle of anticipation, action and reflection to activate transformational competences for the well-being of the individual and of the planet.

Learning Compass 2030

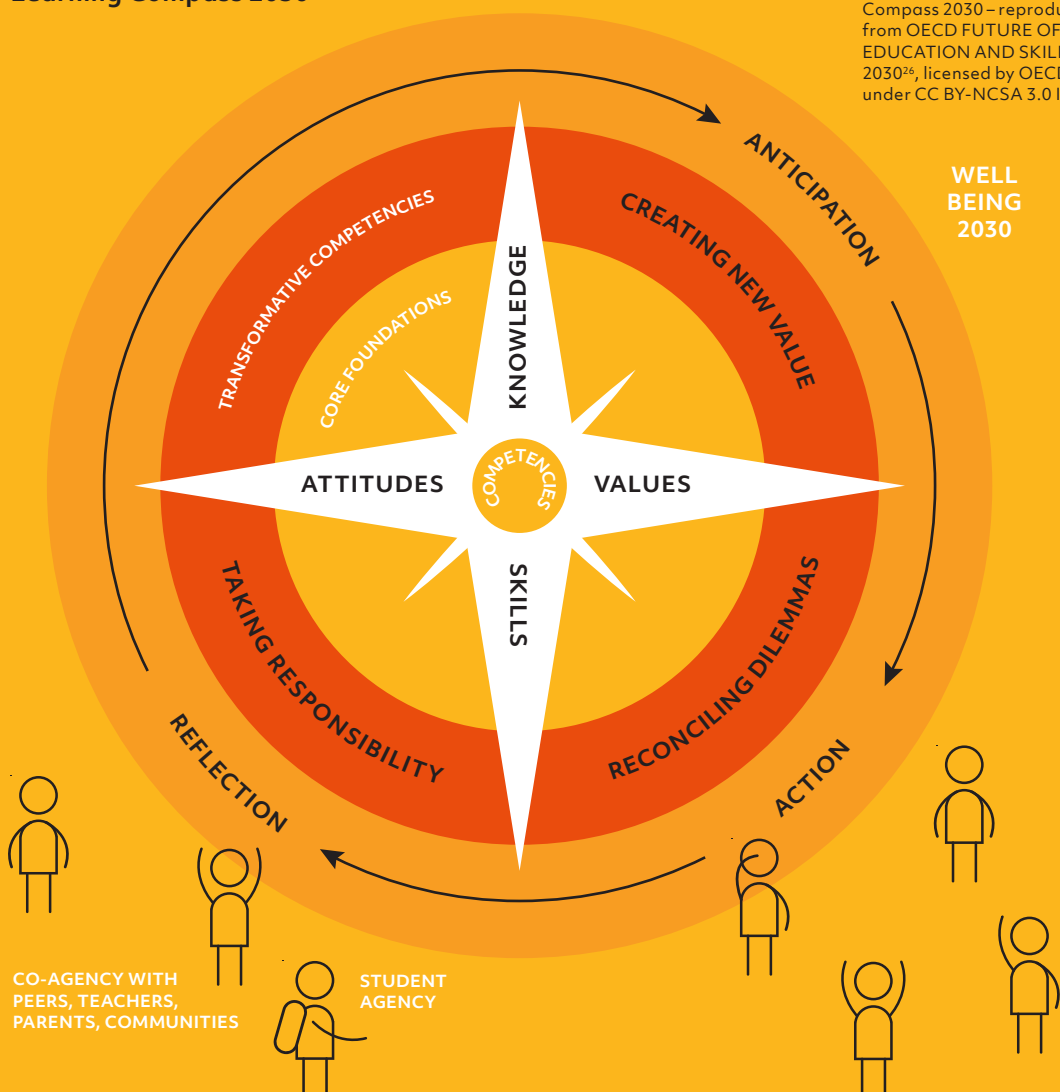


Figure 2: OECD Learning Compass 2030 – reproduced from OECD FUTURE OF EDUCATION AND SKILLS 2030²⁶, licensed by OECD under CC BY-NC-SA 3.0 IG

Integrated STEM Education

STEM education plays a key role within the curricula of the future. Traditionally, the individual STEM disciplines are taught individually, with little focus on the relationships and interdependencies between science, technology, engineering and mathematics.

However, we propose that there needs to be more emphasis on **supporting teachers to integrate the STEM disciplines**. Appropriate pedagogical practice for STEM education incorporates the content knowledge of the individual disciplines, and promotes learning across and between disciplines. It foregrounds the development of solutions to problems rooted in real-world contexts,

utilising engineering design and practices. The appropriate use and application of technology enhances teaching, learning and assessment. This approach allows for the development of “Core STEM competences” (see Spotlight on Practice #5: ATS STEM) - only one of these seven competences relates specifically to STEM knowledge, while the remaining six are competences which will be valuable to all citizens in all walks of life, as they grow and thrive in our complex, connected and rapidly changing society.

Spotlight on Practice #5

ATS STEM - Integrated STEM Education in Practice (Europe)

What does successful integrated STEM education look like in practice? This is the question explored by the Erasmus+ ATS STEM project, funded by the European Commission and led by Dublin City University.²⁷ The project explored the various contested definitions of the term, and has proposed seven characteristics of integrated STEM education.

The “core STEM competences” within this framework represent knowledge, skills and attitudes useful in a wide range of contexts throughout one’s life, not only in school or in a STEM-related career, including the so-called ‘21st Century’ or ‘transversal’ skills.

- Core STEM competences
- Problem solving design and approaches
- Disciplinary and interdisciplinary knowledge
- Engineering design and practices
- Appropriate use and application of technology
- Real-world contexts
- Appropriate pedagogical practices

The major implication of this review and synthesis of literature in STEM education is the need to scaffold an integrated approach to designing STEM learning activities for students that will develop their core STEM competences²⁸.

Core STEM Competences for Integrated STEM Education

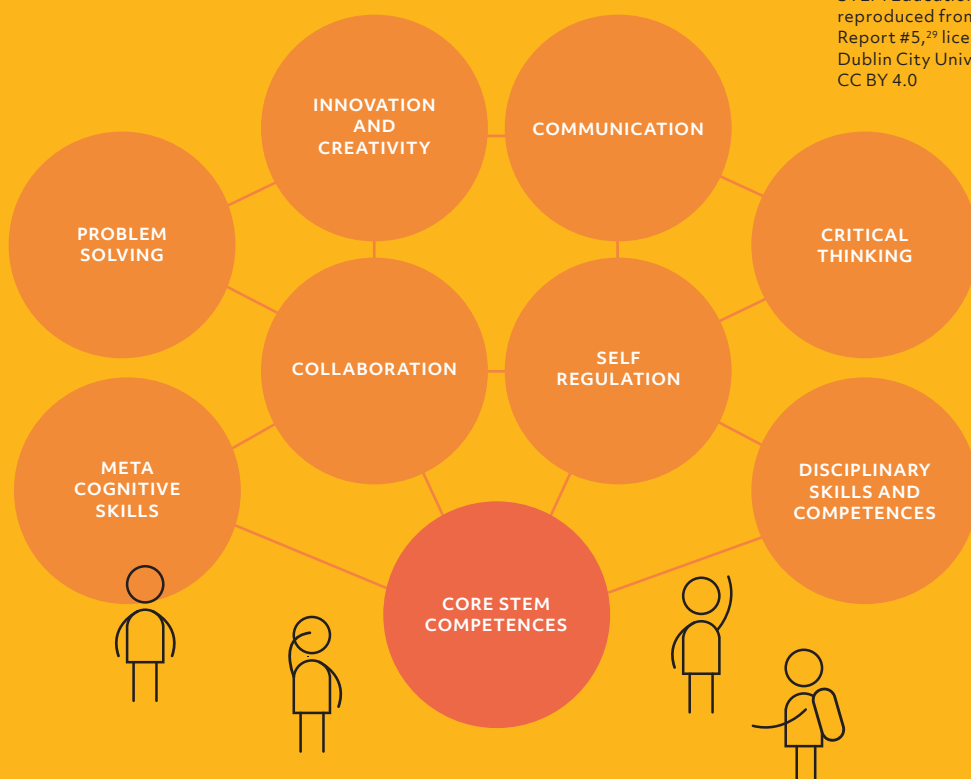


Figure 3: Core STEM Competences for Integrated STEM Education – reproduced from ATS STEM Report #5,²⁹ licensed by Dublin City University under CC BY 4.0

Developing Teachers' Mindsets for Integrated STEM Education

“...it is what teachers do in and outside the classroom that matters the most – and the most directly – for the cognitive and social-emotional outcomes of the school’s students.”

OECD: Positive, High-achieving Students? WHAT SCHOOLS AND TEACHERS CAN DO (2021) , p.4³⁰

With the shift in focus in educational policy towards integrated STEM education, there is also a need for a shift in teacher education. With the rapid technological advances of recent decades, our fundamental ways of living and thriving in society have shifted. The demands on our teachers and educators are similarly changing. They now must be able to design learning environments that embody our globally connected society, and that reflect the complex and interdisciplinary nature of the challenges we face today, and in the future.

Teacher education traditionally involves a series

of classroom placements as part of the process of accreditation. In some cases, teachers’ knowledge of the world of work may be limited to this professional experience. According to the ATS STEM framework (see Spotlight on Practice #5: CHARACTERISTICS), one of the characteristics of integrated STEM education is “real world context”. Preparation of our teachers to design and facilitate integrated STEM education must include an opportunity for future teachers to experience STEM in practice - to truly experience the phenomena they are teaching, and the careers they are advising

their students about, as well as the STEM careers they may not have even known about previously. Not only can they adapt actual industry problems and challenges into classroom teaching and learning opportunities, they can also experience in the STEM workplace the interplay between disciplinary content knowledge and the so-called “transversal” skills and competences such as communication, collaboration, creativity, and critical thinking.

Spotlight on Practice #6

STInt Programme (Ireland)

Through engagement in 12-week summer internships in STEM roles funded by industry, pre-service teachers gain hands-on experiences of a wide range of careers and opportunities available within STEM industries. This enables future primary and post-primary teachers to inspire generations of their own students to develop the STEM competences needed to thrive and shape our rapidly changing world, in a globally-connected society.

In 2016, Dublin City University (DCU) together with Accenture and the 30% Club Ireland launched a pilot STInt Programme for pre-service teachers. The STInt Programme is led by Assoc. Prof. Eilish McLoughlin and Prof. Deirdre Butler from DCU Centre for the Advancement of STEM teaching and Learning (CASTeL). Through the support of the 30% Club Ireland, Connecting Women in Technology (CWIT) and Science Foundation Ireland (SFI), 115 pre-service primary and post-primary teachers have completed internships in STEM roles in 33 leading companies to date.

In 2021, 91% of STInt interns surveyed immediately after participating in the STInt Programme reported that the experience has influenced how they perceive STEM industries and STEM careers, and 84% report they are confident they could develop a learning experience

for students based on something learned during their internship (n = 45 participants surveyed). STInt interns interviewed one year after their 2019 or 2020 internship experience reported increased confidence, resilience and willingness to tackle unfamiliar problems, as well as improved communication, teamwork, and problem-solving skills, along with enhanced disciplinary skills and knowledge. Many interns highlighted how this experience has influenced how they design learning opportunities for the classroom, e.g. using real-world contexts, and/or focussing on developing core STEM competences.

STInt hosts reported the benefit to their organisation of engaging with a programme which provides a coordinated way to work towards their collective organisational goals of diverse and inclusive STEM engagement, in support of future skills needs. Host organisations emphasised the importance of teachers developing an increased understanding of STEM careers and opportunities. In addition, they also highlighted it is important to their organisations that primary school teachers can participate in the STInt Programme, as they feel it is crucial that STEM education and engagement is promoted from a young age.

Many programmes that address youth disengagement with STEM or issues of diversity in STEM often provide an intervention that targets a specific demographic group (very often Transition Year students) or serve a particular geographical region. However, as highlighted in the Goos et al. 2020 report³¹, there is a need to shift away from one-off or short-term interventions that mainly focus on post-primary school-aged students, towards inclusive

STEM education programmes that span the range of ages from early childhood into adulthood. The STInT Programme does just this, building teacher capacity for integrated STEM education, from Junior Infants to Leaving Certificate level in Ireland. Teachers must be given the opportunity to implement integrated STEM education within the curriculum they teach, and the freedom to be curious and creative in how they design for STEM learning. They must

themselves be lifelong learners, continuously improving and updating their knowledge and their practices. While there are

Case Study STEM Teacher Internship 2019 (Pre-service primary teacher)

"This internship showed me that although STEM industries are full of a myriad of employees of varying careers, it's their 21st century skills like communication, creativity and problem-solving that connect them in a common goal. From this experience, I now know I have a responsibility to equip my students with these skills through collaborative and innovative means so they can thrive in these corporations in the future. Teaching coding and computational thinking is where I chose to start!" (Sam, STInt Intern, 2019) (Participants have been anonymised).

Sam is a primary school teacher who completed a STEM Teacher Internship in 2019. Their internship exposed them to coding, and Sam returned to DCU and completed a final year thesis on coding and digital technology integration in maths. In 2020, Sam began teaching 5th Class in a rural primary school. They stayed in touch with fellow interns, and began using lesson plans and coding resources developed by another 2019 intern who had been hosted by Microsoft. Sam's school principal was so impressed, he invested

resources to provide hardware for the whole class. Sam also led the development of a proposal on behalf of their school for a corporate funding grant, and in 2021, the school was awarded €20,000 to support the introduction of coding and computational thinking lessons. Sam is supporting other teachers who are less experienced in using digital technology in the classroom.

"STEM education is invaluable. It's not just buzzwords like coding and computational thinking, it's the skills behind them. It's problem-solving, it's collaboration, it's knowledge creation, it's all those skills and thought-processes behind them that are so important. So you can have all the resources in the world, but you have to instill those skills in children, because those are the things that are going to get them to the jobs that aren't created yet."

In Sam's 5th class. There was a particular student who had very little interest in languages, but who really took to coding and "attached to it like glue". The student raced ahead, finishing work and going on to the next part of the lesson, creating their

own version of the project. This was a moment of realisation for Sam as to how coding could be a pathway to ignite the interests of students at such a vital stage in their education:

"This is the kind of moment that you're like, ok, I need to know more about this stuff. Even for him! Even if it's just him, it doesn't matter. I need to know more of how I can influence this guy, because this is how he learns, this is what he's interested in, and this is what is going to get him...they're coming to that vital age of 11 and 12, where they're getting into their habits. I need to show him there IS something interesting."

Sam has continued the learning journey inspired by the STInt experience, completing a diploma in coding and computational thinking for teachers, and enrolling in a Masters of Education, specialising in Digital Learning. Sam also volunteers with EU Code Week in Ireland, and participates in university-led educational research projects.

"I've learned so much....it's been a real experience for me....I just can't stop learning about it!"

multiple steps to be realised before we achieve truly systemic change, supporting teachers' professional learning around integrated STEM education will impact the greatest number of learners in the short- and medium-term.

The STInt Programme does not only send pre-service teachers 'out into jobs' in industry - it provides them with an opportunity for 'situated learning'³² to develop the skills required for the jobs of the

future within a community of practice, and supports them to connect this learning back to the classroom. It also connects them with industry, with the long-term goal of seeding lasting partnerships between the schools they teach in, and the industries they have worked with. It promotes the development of communities of teacher professional learning. The value of this community beyond the 12-week summer internship was evident in

Sam's case, as the classroom resources provided by another STInt intern in another host organisation kickstarted Sam's passion for digital learning. The three-way partnership between teachers, industry, and the university modelled by the STInt Programme provides a robust model for cross-sectoral and sustained collaboration in STEM education.

Case Study STEM Teacher Internship 2019 and 2020 (Pre-service post-primary teacher)

Chris (Participants have been anonymised) is a post-primary school teacher who undertook STEM Teacher Internships in 2019 and 2020. In 2020, they began teaching science and maths in a large mixed secondary school in an urban location. Chris feels that the internship really prepared them for the period of remote teaching and learning they faced during lockdown and school closures in early 2021. This teacher created videos for classes during this time, something that they learned how to do during one of the internships. This proved to be a great hit with learners, and they got feedback from parents who commented on how useful they were in supporting students' home learning. Increase in technological know-how as a result of the internship has

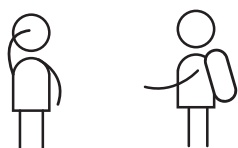
been a huge benefit to Chris in many different elements of their career - enhanced Excel skills means that they have improved how they track students' work, how they do assessment, and how they give student feedback. Chris now shares this knowledge with other teachers in the school, and their newfound openness to technology challenges means that they have undertaken the building of a new school website, even though website building was not something learned during the STInt internship.

"[The internships] allowed me to gain a lot of confidence in that area, so straight away in school I was into helping the IT group out, helping with blended learning, I had a lot more confidence with that, and it benefitted my class group so much when it came to after January and we were in

lockdown again....teachers do know they can come to me and say "how can I do this?"....I'm more open to investigating what a problem on a computer is in comparison to beforehand, when, if an error box popped up, I'd be running away from it."

Chris also mentioned feeling more confident now in advising students about future career options, as a result of having worked in a STEM environment.

In the classroom, when talking about a topic like renewable energy for example, they love being able to say "well this is what a career is like in that sector", based on first-hand experience. Chris thinks that STEM education is really important for students, especially in relation to creativity and exploration.





The background of the slide shows a blurred image of people in a meeting or classroom setting. A man with curly hair in a blue and white checkered shirt is in the foreground on the left, looking towards the right. In the background, a woman is visible, also looking towards the right. The entire image is overlaid with a semi-transparent blue filter.

Recommendations for Shaping Shared Futures

Sustained investment in the STInt Programme beyond the current pilot phase will serve to advance Ireland's position as a global leader in STEM teacher education.

Recommendations for Shaping Shared Futures

"In line with our ambition to have the best education and training service in Europe by 2026, Ireland will be internationally recognised as providing the highest quality STEM education experience for learners that nurtures curiosity, inquiry, problem-solving, creativity, ethical behaviour, confidence, and persistence, along with the excitement of collaborative innovation"

Department of Education and Skills, Ireland:
STEM Education Policy Statement 2017-2026, p. 12

The STEM Education Policy Statement 2017-2026 sets out a clear vision to shape the direction of STEM education in Ireland.³⁵

This section outlines two key recommendations which will simultaneously address the critical issues outlined in the previous section, and

support the realisation of this ambitious policy statement within the coming years.

Strengthen teachers' understanding of integrated STEM education through real-world STEM experiences

The STInt Programme offers a unique model to support teachers adopting integrated STEM education by providing an opportunity for future teachers to gain first-hand experience in a STEM workplace. It is estimated that throughout their career, a single primary teacher will influence 1000 students, while for a post-primary school teacher, that figure is estimated to be 5000. (Calculated on the basis of a 40-year career, with 25 students per year for primary teachers, and 125 students per year for post-primary teachers)

From an initial pilot which placed five Dublin City University (DCU) pre-service teachers in one host organisation (Accenture) in 2016, in 2021, the STInt Programme offered remote-working internships to 45 pre-service primary and post-primary teachers from nine degree courses following specialisms in science, mathematics or digital learning in Dublin City University,

Maynooth University and University College Dublin. The target for the STInt Programme in 2022 is to place 75 pre-service teachers in STEM roles in industry nationwide, and achieve more than 180 internships awarded since the inception of the programme. The host organisations in the first six years represent various sectors, including bio-pharmaceuticals, technology, engineering, technology consulting, telecommunications, energy, including renewables, and finance. In order to reach 2022 targets, it will be necessary to expand into further sectors to enlist a wide range of companies into the STInt Programme.

Sustained investment in the STInt Programme beyond the current pilot phase will serve to advance Ireland's position as a global leader in STEM teacher education. Opportunities to expand this programme include mandating it within the requirements of teacher

education for all primary and post-primary school teachers of STEM subjects; making it available to teachers preparing to become career guidance counsellors; and offering similar opportunities for in-service teacher professional learning in STEM industries.

Scaling the programme to national level and achieving these extended targets will require coordinated cross-sectoral collaboration between higher education, government, educational governing bodies, and STEM industries.

Structure and Strengthen STEM Learning Ecosystems

The Covid-19 pandemic brought to light the capacity for our education systems to shift to remote learning almost overnight, and the crucial role of the family, the home and the environment in the educational experiences of our young people. We were reminded of the potential for technology to positively impact schooling, and of the role of teachers as 'designers and facilitators of learning' rather than 'holders of knowledge' or as often referred to, "the sage on the stage".

As we reflect on the radical shifts experienced during the pandemic, it is pertinent to consider whether some of the changes that were implemented through necessity could or should become longer-term features in our education systems - for example the increased involvement of families, the use of technology, or the fluid boundary between in- and out-of-school learning environments?

In recent years, there has been a growing trend in educational research towards ecological and systems perspectives³⁴. Borrowing from the field of evolutionary biology³⁵, the concept of learning ecosystems allows us to shift our understanding away from the idea that education is solely the responsibility of an individual species (schools), but rather that schools are integrated into more comprehensive systems, wherein interdependent relationships are at play between species, i.e. family, community and non-formal learning organisations as well as schools. Diverse species play different roles in relation

to individual learners, and these relationships vary over time. As an ecosystem depends on its environment, system-level effects - e.g. national educational policy - will also affect the learning ecosystem.

Any individual exists within a particular learning ecosystem that affects them in myriad ways throughout the course of their lifelong learning journey. In relation to STEM learning for example, a young person may encounter and engage with STEM through a family visit to a museum, or become interested in engineering by working on personally meaningful projects at a youth club. They may consume STEM-related media in their spare time - online, in print or on TV. They may become involved in climate activism through a local voluntary organisation. A student in an area which is home to STEM industries who are deeply engaged with the local community and schools may have a very different learning ecosystem from someone in an area without similar access to STEM role models.

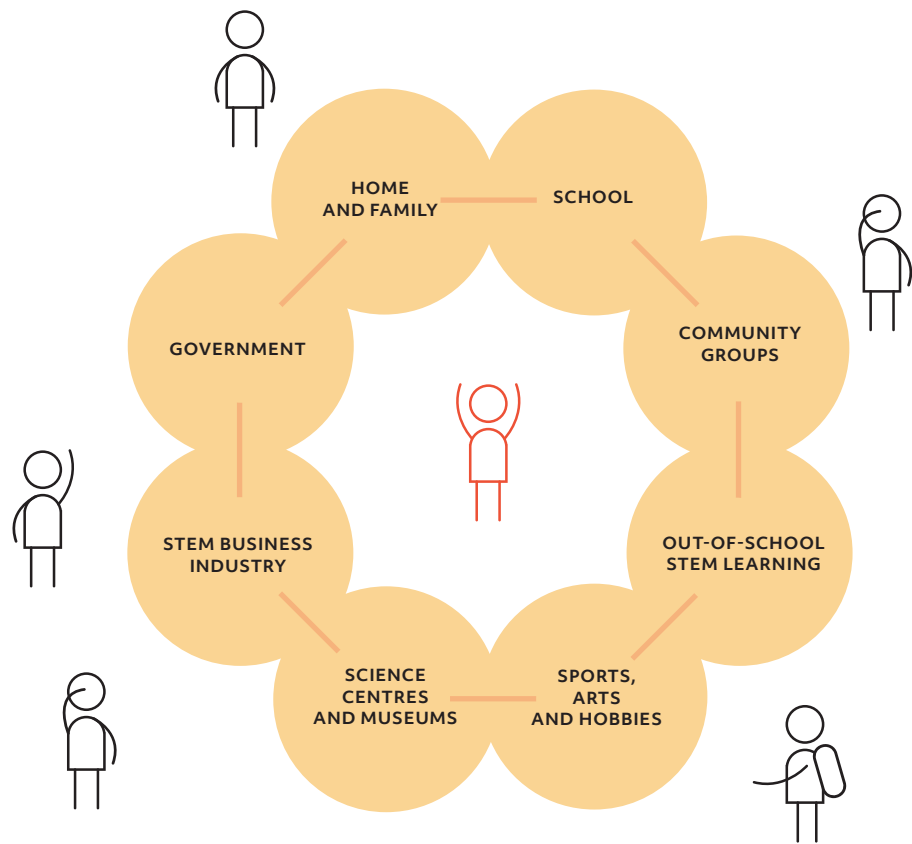
While a great many resources and initiatives exist to promote STEM education and engagement, these are often siloed - industries may partner with particular schools or programmes, interventions may be focused on gender or particular student cohorts or teachers may not be aware of a student's involvement in out-of-school STEM activities. Greater cohesion among these diverse species in a learning ecosystem can strengthen progress towards a shared goal of increasing

STEM engagement and participation for all. Echoing the advice presented in the Goos et al. (2020) review, commissioned by the Department of Education³⁶, we recommend that the Irish STEM learning ecosystem be developed, strengthened and structured across all educational levels

In 2014, a report commissioned in the US by the Noyce Foundation³⁷ presented the concept of STEM learning ecosystems as structured collaborations encompassing schools, community initiatives including after-school and summer STEM programmes, as well as science centres and museums. Designed pathways support a student's connected STEM learning journey through childhood and adolescence. Since then, the STEM Learning Ecosystems Initiative³⁸ has emerged, which supports the efforts of regional collectives to organise into STEM Learning Ecosystems. At the time of writing (October 2021), this global community of practice represents 94 locations in the USA, Canada, Mexico, Israel and Kenya.

My STEM Learning Ecosystem

Figure 4: Example of a STEM Learning Ecosystem



The value of a structured regional approach to STEM teaching and learning is that the ecosystem members can work collaboratively to ensure there are appropriate supports or interventions for young people at every age. It can also identify uniquely local challenges and devise locally appropriate solutions, drawing on a wide range of expertise and input. Investment in STEM education can be done systematically rather than through a piecemeal

approach, and STEM supports can be developed over longer timescales. Innovative approaches to accreditation for learning may be adopted, with awards, badges or certifications earned in out-of-school or digital spaces carrying credit within formal learning systems, as is the case with the LRNG Platform in the US³⁹. Learning ecosystem partners will be well positioned to work collectively to advocate for policy change, or to bid for funding. Finally, such

a community of practice can encourage knowledge exchange and peer-to-peer learning and mentoring.

Spotlight on Practice #7 “Our Neighborhood” (USA)

A project of STEM Learning Ecosystems Community of Practice and TIES (Teaching Institute for Excellence in STEM), Our Neighborhood⁴⁰ is intended to mobilize and align all sectors of a STEM Learning ecosystem.

The project aims to give all leaders within ecosystems strategies and concrete actions to engage, sustain and uplift families and communities. Resources include curated research, interviews and videotaped panel discussions and inspiring stories and practices, and are aimed at seven key stakeholder groups: family and home, early childhood, K-12 school (U.S. terminology, approximately equivalent to primary & post-primary school ages in Ireland), post-secondary and training, out-of-school time, business and industry, and government.

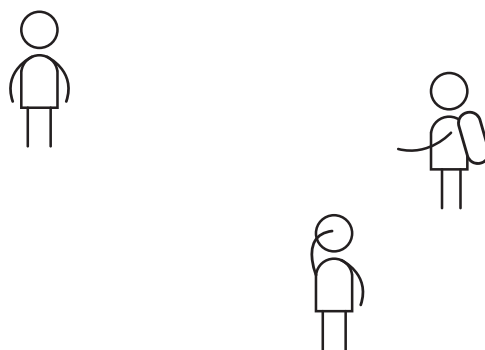
Read more about an inspiring practice: ‘In Constant Communication: Queens, NY Science Hall builds a space the community desires’⁴¹.

Spotlight on Practice #8 Netherlands Regional Network (NL)

In the Netherlands, ten regional networks bring together groups comprising universities, schools and companies, and civil society organisations including science centres and museums. In total, 22 universities of applied science, 12 universities and 350 schools are involved. These networks engage over 27,000 pupils and 3,800 teachers annually, with a programme of formal and informal learning activities, each with a strong local identity. The 10 networks are part of a national coordination council which supports cross-regional collaborations, exchange of good practices and peer learning⁴².

The Irish STEM Education Policy Statement 2017-2026⁴³ states that "Stakeholders will engage in a coordinated approach to provide a world standard STEM education eco-system" (p. 14), with a vision for 2026 that "Robust relationships between schools and HEIs, research agencies, business and industry, professional bodies, science centres, media and government agencies are in place". Much groundwork is already underway in this space in Ireland - for example, the research carried out by I Wish⁴⁴ and Accenture in Ireland⁴⁵, and the mapping of informal science learning opportunities carried out by the SySTEM 2020 project⁴⁶. However, there is still much that can be learned from international examples of collaboration and cooperation to nurture flourishing STEM learning ecosystems here in Ireland.

Through its innovative approach to teacher professional learning, network of HEIs, and brokering of opportunities for industry partners to invest in STEM education, the STInt Programme, led by Dublin City University, could form the basis of such a world-class STEM learning ecosystem. With targeted coordination support, this network of engaged stakeholders could be supported to grow, and to provide enhanced STEM learning opportunities and pathways for all young people in Ireland.





Concluding Remarks

The key competences developed through an integrated STEM approach are valuable beyond a career in STEM - they are the competences which will allow future generations to work collaboratively to imagine and realise a better future for our planet.

All individuals benefit from learning experiences that push them to actively engage with what is going on in the world around them. Becoming active learners, social contributors, collaborative critical thinkers, resilient problem solvers, effective communicators, courageous dreamers, as well as being able to reflect on their own learning, setting their own goals and working across disciplines - these are some of the competences which will be crucial to an individual's success during and beyond their school years. This focus on competences becomes increasingly imperative as we consider the fact that many of the jobs of the future do not even exist yet - hence future generations must be ready to learn and adapt as our world changes around them.

As Covid-19 has shown, complex global challenges require responses coordinated across sectors, and across geographical boundaries. While STEM education is crucial for citizens to thrive in our knowledge economy, it is one element in a number of complex, intertwined systems. The global educational agenda is shifting in light of social injustice and threats to democracy and civil liberties. While effectively preparing teachers for integrated STEM education, and convening structured STEM learning ecosystems will go a long way to achieving equity in STEM, it is also essential that efforts towards change are embedded within wider systemic reforms in education. According to Hecht & Crowley (2020)⁴⁷, educational improvement is a wicked problem

that is “not just complicated but complex” - it is chronic, non-linear and unpredictable.

Integrated STEM education is a cornerstone of the future of education. The key competences developed through an integrated STEM approach are valuable beyond a career in STEM - they are the competences which will allow future generations to work collaboratively to imagine and realise a better future for our planet.

To achieve integrated STEM learning opportunities in the classroom, we must support our teachers during their pre-service education and ongoing professional learning to increase their knowledge and understanding of STEM in action in real-world contexts. We provide robust evidence based on six years of the STInt Programme, which indicates that STEM teacher education can be significantly enhanced when it includes professional learning not only in the classroom, but in authentic STEM workplaces.

Finally, we need to think at scale to be able to consider the multiple intersecting challenges and barriers to educational equity. Making adjustments to long-term established schooling models is a complicated task, but it is not impossible. Systemic change will require joined-up thinking and action, based on evidence. Any such action must capitalise on the connecting networks of organisations and individuals who are already working to shape a new future for education and ensure that future efforts harness all of our collective expertise and values. Crucially, if the ambitious goals

of the current STEM Education Policy are to be realised, it must be universally supported across party lines, and be sustained in the face of any cabinet changes.

So what actions can be taken in the short-term to achieve these large-scale ambitions? In the Irish Government's STEM Education Policy Statement (2017 – 2026) there are several references to the need for increased connection between educators and industry, including the following:

“Business and industry will engage in partnerships with schools with a focus on how they can best support STEM education in our schools and provide learners with an insight into how STEM learning can develop into a career in STEM” Department of Education and Skills, Ireland: STEM Education Policy Statement 2017-2026, p. 20

A 12-week immersion in STEM industry is sufficient to give a pre-service teacher a transformative view of the transversal skills and competences needed for the future success of their students.

This maps directly onto the objectives of the STInt Programme, and its participating universities and host organisations. As the Irish Government heads towards Phase 3 of the implementation of their STEM Education Policy (2023-26), the STInt Programme, now in its sixth year, is primed to be extended into a nationwide programme including all institutes and universities offering science or STEM teacher education courses.

It is timely for the Irish Government to invest in the STInt Programme to enable its scaling for nationwide adoption, therefore supporting the realisation of this important objective of the STEM Education Policy (2017 – 2026). The testimonials shared by teachers

Sam and Chris in this White Paper illustrate exactly how the STInt Programme can be successful and how a 12-week immersion in STEM industry is sufficient to give a pre-service teacher a transformative view of the transversal skills and competences needed for the future success of their students. Let's make sure every young person in Ireland gets the chance to be taught by a teacher like Sam or Chris!



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This White Paper presents an ambitious vision for the type of education system required to prepare learners for the future. It contains a strong focus on integrated science, technology, engineering and mathematics (STEM) education, essential for developing the necessary competences to thrive in our complex, ever-changing world.

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