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Full STEAM ahead - Implications for Teacher Education in the Context of Curricular and Policy Reform in Ireland

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Abstract. STEM and more recently STEAM have become core aspects of Government policy and educational reform throughout the world. There is a central focus on preparing citizens and graduates who have expertise in STEM disciplines to drive innovative societies and economic ambitions. In many cases these changing policies are in response to the opportunities and challenges of the fourth industrial revolution. In this paper, an overview of STEM policy and related curricular reform in Ireland is presented. Specific attention is paid to the importance of and implications of these policies for teacher education. It is argued that the role of the teacher, and by extension the role of teacher education, is now more complex. Challenges in preparing pre-service teachers (PSTs) to engage in pedagogical practices, including assessment, which they may not have experienced as learners are discussed. Additionally, it is proposed that there is a need to identify skills PSTs need to develop before they can effectively prepare their students for a changing society.

Keywords: STEM education, STEAM education, teacher education

1. Introduction

The modern world is in a state of change. Technological and scientific discoveries are having influences on the fabric of society, altering how people communicate, study, do business, manufacture, etc. The future holds many unchartered territories considering developments in areas such as artificial intelligence, gene editing, nanotechnology. While these are often referred to as 'advancements' the world is still facing many challenges including climate change, food and water security, energy production, political unrest and inequality which raises the question about humanities ability to deal with these changes. In 2016, at the World Economic Forum in Davos, Klaus Schwab stated that the world is now in the 4th Industrial Revolution. The World Economic Forum website states that:

"The Fourth Industrial Revolution represents a fundamental change in the way we live, work and relate to one another. It is a new chapter in human development, enabled by

extraordinary technology advances commensurate with those of the first, second and third industrial revolutions. These advances are merging the physical, digital and biological worlds in ways that create both huge promise and potential peril. The speed, breadth and depth of this revolution is forcing us to rethink how countries develop, how organisations create value and even what it means to be human. The Fourth Industrial Revolution is about more than just technology-driven change; it is an opportunity to help everyone, including leaders, policymakers and people from all income groups and nations, to harness converging technologies in order to create an inclusive, human-centred future. The real opportunity is to look beyond technology and find ways to give the greatest number of people the ability to positively impact their families, organisations and communities."

This statement rightly highlights both opportunities and challenges that lay before the world. It also identifies that the pace of change is much faster than any previous revolution. It raises questions about ethics, human rights, employment, equality etc. Many of these issues are already identified in the 17 United Nations Sustainable Development Goals (2015) and are serious challenges facing the world[12]. in its document Rethinking Education Towards a Global Common Goal notes that education has an important role to play. It states that "Education must be about learning to live on a planet under pressure. It must be about cultural literacy, on the basis of respect and equal dignity, helping to weave together the social, economic and environmental dimensions of sustainable development." This sentiment is also reflected in European Union (EU) reports relating to STEM education such as Science Education Now: A renewed pedagogy for the future of Europe and Science Education for Responsible Citizenship. These reports call for changes in education policy and practice to better prepare students as future citizens. They call for a move towards inquiry-based teaching methods, to engage students with scientific phenomena and to make curricula more interesting and engaging for female learners. They also recognise the importance of good quality teaching as the foundation of science education. In the latter report, a need for acquiring competencies, abilities to collaborate, listening to ideas, thinking critically, problem solving are all explicitly called out. Additionally, it ascertains that science education is vital to addressing the worlds grand challenges. Finally, it points towards a need for connections to be made between STEM and all disciplines, referred to as STEAM, in order to produce innovative new ideas and create solutions.

The purpose of this paper is to present an overview of curricular and policy changes in Ireland and their implications on Initial Teacher Education (ITE) and consequently the preparation of preservice teachers (PSTs). The paper will first outline an overview of the Irish Education System to provide a context for the discussion. Following from this, exemplars of tasks from a science pedagogy module and their rationale will be presented. These will be used to identify curricular and policy changes in Ireland and explain how the author is attempting to address them in an ITE context. Given the potential breath of this topic, the paper will specifically focus on recent reforms of the Junior Certificate – Second Level Science Specification.

2. Overview of Irish Education System

State education in Ireland consists of primary education, second level, third level, further and adult education and special needs education for students with disabilities. Pre-school education in usually provided by private stakeholders who receive funding from the state under the Early Childhood Care and Education (ECCE) scheme. This is open to children from the age of 2 years and 8 months until they enter primary education or are not older than five years and 6 months. Enrolment in school is compulsory for students from the

age of six to 16 years however, the majority of students normally commence primary education at four or five years of age and complete second level education at 17 or 18 years of age. Second level education is divided into Junior Cycle and Senior Cycle, each of which have state assessments. Education for students with special educational needs is catered for through either enrolment in mainstream classes with additional supports, in a special class in a mainstream school or through enrolment in a special school which caters for their specific disability. On completion of second level education students have multiple options. They can seek employment or apply for third level education provided by universities, technological universities, institutes of technology and colleges of education. Alternatively, if students do not enter the university sector or workforce, they can apply to the further and adult education sector which provides a wide variety of post-leaving certificate courses such as horticulture, tourism, childcare and community care through Education and Training Boards.

The National Council for Curriculum and Assessment (NCCA) is a statutory body of the Department of Education and skills that advises the Minister on curriculum and assessment for early childhood, primary and second-level education. Additionally, it advises on assessment procedures used in schools and examinations on curriculum subjects. However, it is not responsible for implementation or assessment of curriculum. The latter falls under the remit of the State Examinations Commission who develops, assesses and accredits second-level examinations. Third level education institutions offer and accredit a range of qualifications from higher certifications to doctoral degrees. All qualifications offered are benchmarked on the Irish National Framework of Qualifications (NFQ) ranging from level one to level ten (figure 1).

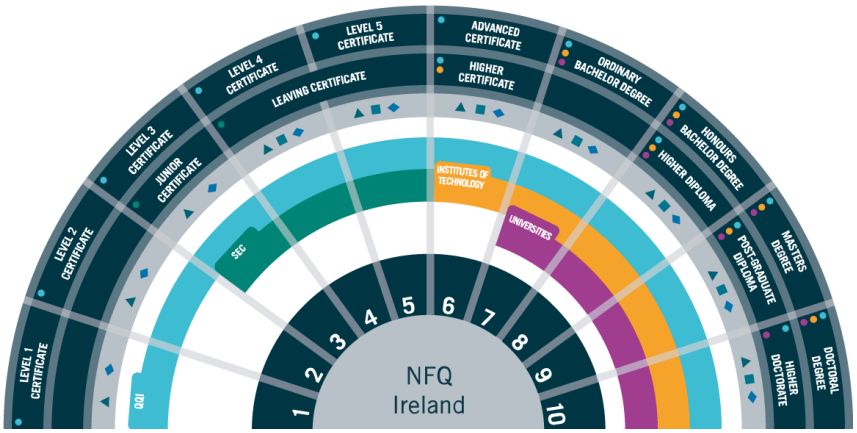

Figure 1: National Framework of Qualifications (NFQ)

There are no formal integrated STEM courses in the Irish curriculum. At primary level Mathematics has a set curriculum while Science is captured under an integrated curriculum of Social Environmental and Scientific Education along with Geography and History. In the Junior Cycle of second-level education STEM subjects include Science, Technology, Material Technology (Wood) and Metalwork, Technical Graphics and Mathematics. At Senior Cycle additional subjects are taught including Physics, Chemistry, Biology, Agricultural Science, Construction Studies, Applied Mathematics. A full list of the STEM subjects at the various levels if provided in figure 2. There has been a recent review of the Junior Cycle with the creation of new specification. A similar review is ongoing for Senior Cycle.

Sector	Area	Subject
	Science	Science
Primary	Technology	Although not a curriculum subject per se, the use of ICT, as a means of enhancing teaching and learning, is promoted across the primary school curriculum
	Mathematics	Mathematics
Junior Cycle	Science	Science
	Technology	Technology, Material Technology (Wood), Metalwork
	Engineering	Technical Graphics
	Mathematics	Mathematics
Senior Cycle	Science	Biology, Chemistry, Physics, Agricultural Science, Physics & Chemistry
	Technology	Technology, Design and Communication Graphics
	Engineering	Engineering, Construction Studies
	Mathematics	Mathematics, Applied Mathematics

Figure 2. STEM Curricula in the Irish Education System.
from STEM: Education in the Irish School System, 2016

Overview of Initial Teacher Education Routes

The Teaching Council of Ireland is the professional standards body for the teaching profession. They are charged with regulation of professional standards of teaching. In this regard they produce the Initial Teacher Education criteria and guidelines for programme providers which are used to accredit ITE programmes. These programmes are provided by colleges of education and universities. There are two main routes to qualify as a teacher in Ireland at primary or second level. The first route involves completion of a four-year level 8, 240 ECTS bachelor's degree which combines subject disciplines, foundation and professional studies and school placement. The second option is to complete a two-year 120 ECTS professional Master of Education (PME) degree post completion of a level-8 bachelor's degree which has relevant and recognised modules for the teaching qualification sought. In table 1, a description of the areas of learning relating to Foundation Studies, Professional Studies and School Placement are detailed.

Table 1. Overview of Initial Teacher Education Areas of Study. Adapted from the Initial Teacher Education: Criteria and Guidelines for Programme Providers (March 2017)

Areas of Learning	Description of Areas of Learning
Foundation Studies	• include curriculum studies, the history and policy of education, philosophy of education, psychology of education, sociology of education • through macro curriculum studies, develop students' understanding of, and capacity to critically engage with, curriculum aims, design, policy, reform, pedagogy and assessment • enhance students' understanding of the Irish education system, locate it in context and enable students to think critically about it • provide research-informed insights into student teachers' understanding of the practices of teaching, learning and assessment • illuminate key dimensions of the professional context in which the thinking and actions of teachers are carried out • provide the basis of a strong professional ethic in teaching.
Professional Studies	• include subject pedagogies (methodologies) and curricular studies • develop pedagogical content knowledge • advance the communicative skills of student teachers • ensure that teaching itself is understood and practised as a form of self-critical learning by student teachers, with ample opportunities for teamwork and enquiry-based initiatives with colleagues.
School Placement	• integrate theory and practice • plan for, and undertake, class teaching, learning and assessment using a wide range of strategies • develop classroom, organisational and behaviour management skills • observe experienced teachers teaching and be involved in a wide range of school activities • reflect critically on their practice • receive and respond to feedback on their practice • seek and receive advice and guidance in a supportive environment.

In addition to these areas of study there is a strong emphasis on the development on the teacher as a professional reflective practitioner. This is noted as a mandatory element of the Initial Teacher Education criteria and guidelines [6].

3. Irish Curricular & Policy Reform

As noted, there has been a recent review of the second level Junior Cycle in Ireland. This resulted in the NCCA (2015) Framework for Junior Cycle which provided a blueprint for subject specification development over the past number of years. This Framework (2015) calls for a balance between 'learning subject knowledge and developing a wide range of skills and thinking abilities' and places a focus on 'active and collaborative learning'. Emphases are placed on investigation, information analysis and problem solving. The most significant change in the new Framework (2015) saw the introduction of eight key principles, 24 statements of learning and eight key skills which guide and inform learning within the Junior Cycle (See table 2 & 3). These features help to make explicit the noted balance between knowledge and skills. They are intended to cross all discipline areas and are expected to be a core aspect of the student experience and development throughout their three years of study.

Table 2. List of Key Principles and Key Skills from the Framework for Junior Cycle (2015)

Junior Cycle Principles	Junior Cycle Key Skills
Learning to learn	Managing Myself
Choice and Flexibility	Staying Well
Quality	Managing Information and Thinking
Creativity and Innovation	Being Creative
Engagement and Participation	Working with Others
Continuity and development	Communicating
Inclusive Education	Being Literate
Wellbeing	Being Numerate

Table 3: Sample list of Statements of Learning from the Framework for Junior Cycle (2015)

Sample Statements of Learning
• creates, appreciates and critically interprets a wide range of texts • has an awareness of personal values and an understanding of the process of moral decision making • appreciates and respects how diverse values, beliefs and traditions have contributed to the communities and culture in which she/he lives • values what it means to be an active citizen, with rights and responsibilities in local and wider contexts • values local, national and international heritage, understands the importance of the relationship between past and current events and the forces that drive change • understands the origins and impacts of social, economic, and environmental aspects of the world around her/him • has the awareness, knowledge, skills, values and motivation to live sustainably • makes informed financial decisions and develops good consumer skills • recognises the potential uses of mathematical knowledge, skills and understanding in all areas of learning • describes, illustrates, interprets, predicts and explains patterns and relationships • observes and evaluates empirical events and processes and draws valid deductions and conclusions • values the role and contribution of science and technology to society, and their personal, social and global importance • uses appropriate technologies in meeting a design challenge

Currently there are ongoing specification redevelopment at Primary and Senior Cycle levels. It is anticipated that these will build coherence between Junior Cycle and Senior Cycle. In the context of STEM subjects, it is assumed they will be informed by both the Action Plan for Education [5] and the STEM Education Policy [4]. The Action Plan [5] includes key objectives which make reference to promotion of wellbeing, development of critical skills, knowledge and competencies for participation in work and society. These demonstrate what would be a continuity of the Junior Cycle development into Senior Cycle. It also specifically addresses a need to 'equip teachers with the right skills for 21st century teaching and learning and improve school leadership' which has implications for those providing both initial and in-service teacher education. The STEM Education Policy 2017-2026[4] reflects aspects of the Action Plan for Education [5]. Similar themes relating to the need for learners to develop knowledge, skills (critical thinking, problem-solving, inquiry-based learning and team working), and creativity for addressing real life situations are expressed in the policy statement. The Digital Strategy

for Schools 2015 – 2020[2]: Enhancing Teaching, Learning and Assessment is another policy reform that is expected to influence the Senior Cycle review. This policy document advocates effective embedding of digital learning through development of teachers' pedagogical content knowledge towards a constructivist pedagogical orientation where their use of ICT in teaching and learning moves from substitution to enhancement.

4. Implications of Curricular and Policy Reform on Initial Teacher Education

It is evident from the curricular reforms highlighted that the role of the teacher is becoming increasingly complex. There are now more expectations on personal and skill development of the learner relating to promotion of effective citizenship. Additionally, in the new curricular specifications, greater importance is being placed on interconnected learning within and across the curriculum. These in turn make the part of the Initial Teacher Educator more complex. In this section an overview of a science pedagogy module being taught on a second level Professional Master of Education programme will be described to highlight attempts to address these challenges and as a context to further illustrate reforms at Junior Cycle. Students enrolled in this module will be later qualified to teach subjects listed under the science categories in figure 2.

Module Design and Philosophy

The design and philosophy of the module is built upon the idea of teacher empowerment. It is argued that in educating PSTs there needs to be a focus on preparing them for future landscape changes as much as preparing them for current reforms. It is also designed on the assumption that PSTs may not have experienced the pedagogical approaches being advocated as learners. In this regard it can be difficult for them to envisage how to implement these strategies and can sometimes lead to their questioning the usefulness of such approaches. With this in mind three interconnected core pillars (figure 3) are adopted in the module.

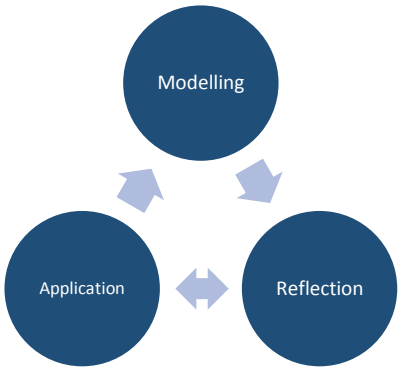

Figure 3. Module Core Pillars

The approach requires the Teacher Educator (TE) to model practices being advocated. There are explicit reflection opportunities for PST to critique their learning and instructional approach during the lessons. They later have occasions to apply the learning and once again reflect either individually or with peers on these experiences. In addition to modelling specific instructional approaches, the TE also embeds cross cutting aspects into activities when appropriate. Table 4 outlines sample content and cross cutting

aspects currently included in the module. In the next section, three examples of tasks used in the module and their relation to curricular reform are explained. These tasks will range from a short episode to full workshop activities.

Example 1: Teacher Identity

This example is a very simple introductory task completed in the first lecture of the module. PSTs are asked to write a narrative of their teaching beliefs and asked to answer three questions:

- Why do you want to teach science?
- What is your measure of being a successful science teacher?
- What do you want your students to be able to *do* having completed their learning in science?

This is discussed and shared as a class. After which the PSTs are introduced to the salient points from key EU and Irish Policy documents as well as the NCCA (2015) Framework for Junior Cycle. Comparisons are made between their narratives and policy documents. On completion of this task with different groups, it is observed that there tends to be strong alignment of their beliefs with the direction of recent policies. However, uncertainties regarding how to develop some areas of learning such as key skills have also been identified. Often there is an underlying sense of the PSTs being overwhelmed with having to develop, what they see at this stage as additional aspects to the specification. In addition to the core focus, this task is found to be have been a positive ice-breaker activity for use with a new group. It gives them opportunities to share previous learning experiences and their beliefs as teachers. The facilitation of this sharing aspect is briefly reflected on as part of the modelling pillar.

The extension of this activity involves discussing an article[8] Educating Science Critics, Connoisseurs and Creators What Gifted Students Must Know about How Science Functions and a conference presentation[8], The many reasons we teach science and what everyone should know about how it works. In these McComas identifies 7 ‘C’s as some of the reasons for teaching science.

1. Learners today may become the **Creators** of Science tomorrow
2. Learners may become **Critics** of science tomorrow
3. Learners may become **Consumers** of science tomorrow
4. Learners will become **Citizens** of science tomorrow
5. Learners should become **Connoisseurs** of science
6. Learners should move from basic **Cognition to Caring**
7. Learners should become science **Connectors** tomorrow

Following a discussion of this work the PSTs are posed the following question: If you believe these (7Cs), what are the implications of these for your teaching? In this activity PSTs are challenged to adapt a lesson to embed elements from the 7Cs list. In addition to individual work, a mixture of peer sharing, and peer review are modelled and reflected upon. PSTs find the application part of this task challenging. While they advocate and

align with many of the areas of learning in the Junior Cycle framework, they struggle to identify approaches which can be utilised to develop these learnings at this stage. The key outcome is that through the three pillars approach, PSTs' awareness of policy reform, curricular developments and new pedagogical strategies are developed. However, it also identifies PSTs feeling of being overwhelmed about incorporating these aspects into their teaching and that they can often see them as add-ons as opposed to areas of learning that can be integrated into science teaching.

Example 2: Teaching from Phenomena

The second example was inspired by the University of Washington's Tools for Ambitious Science Teaching legacy case study on Fungi and Life Processes. It introduces PSTs to the idea of teaching from phenomena and to the importance of linking concepts to enhance students learning. It is also used to increase their awareness of the new science specification, to support their creation of units of work and to develop their understandings of the working collaboratively key skill.

In order to fully explain the rationale for the task a brief overview of the specification is now presented. Enhanced scientific literacy, the development of students capacity *to make contributions to political, social and cultural life as thoughtful and active citizens who appreciate the cultural and ethical values of science*, and the *development of analytical thinking skills such as problem-solving, reasoning, and decision-making*' are key features of the most recent specification (DES, NCCA, 2015). The introduction of five strands, four contextual (*Physical world, Biological world, Chemical world, Earth and space*) and one unifying (*Nature of science*) marks a structural change to the specification (See figure 4). It is a more integrated specification due to the inclusion of four cross cutting elements namely, building blocks, systems and interaction, energy and sustainability. A description of these are provided in table 5. The specification is learning outcome focused. It comprises of 46 outcomes which are divided into the contextual and unifying stands. These describe the understanding, skills and values that each student is expected to be able to demonstrate on completion of the programme. It is anticipated that teachers would select from these learning outcomes and combine them together when designing teaching units. For example, learning outcomes from the building blocks section of physical world, biological world and from the understanding about science section of the Nature of science unifying strand could be combined for a series of lessons. In this way the teacher is making greater links between the contextual strands and incorporating Nature of science into each lesson. This marks a radical change in approach as previously many lessons would often be dictated by the order and sequence of chapters from textbooks which listed chemistry, biology and physics as separate areas of study. The specification includes a section on teaching and learning which specifically references a need to include a variety of teaching strategies to meet the intended learning outcomes. It notes that students should be provided with scaffolded student-led inquiry experiences and that students should have opportunities to engage with contemporary issues in science.

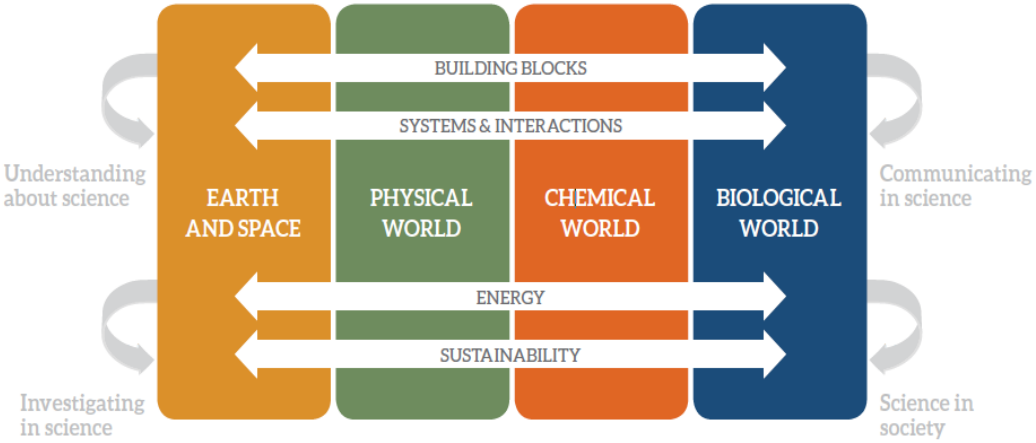

Figure 4. Elements of new science specification showing integrated nature (DES/NCCA 2015)

Table 4. Description of elements of the contextual strands (DES/NCCA 2015)

Building blocks	Focuses on the essential scientific ideas that underpin each strand.
Systems and interactions	Examines how a collection of living and/or non-living things and processes interact to perform some function/s: there is a focus on the input, outputs, and relationships among system components.
Energy	A unifying concept that students can develop across the strands: it is an obvious integrating element as all phenomena we observe on earth and in space involve the transformation and variation of energy.
Sustainability	Focuses on the concept of meeting the needs of the present without compromising the ability of future generations to meet their needs.

Having presented the overview of the specification the PST task is now described. PSTs are provided with one PowerPoint slide on which there is an image of decomposing strawberries. They are divided into small groups and asked to list the learning outcomes from the specification which could be used to explain the phenomena in the photograph. The experience to date is that the task pushes PSTs out of their comfort zone. It forces them to interrogate the specification outcome by outcome and to consider possible links which they would not have completed previously. After sharing and discussing their lists, a master list of generated on the whiteboard. On one occasion the PSTs identified 24 outcomes including a minimum of two from each strand that could be taught through the phenomena. The majority came from the biological world strand closely followed by outcomes from the Nature of science strand. The extension task requires PSTs to create

an outline of a learning sequence that they would use to explain the phenomena and to consider the duration of the sequence. These outlines are later peer reviewed. Finally, a reflection activity is used to encourage the PSTs to internalise the learning from the task during which they reflect on the peer strategies (*collaboration and critique*) modelled, on their awareness of the specification and ability to link the strands and embed the unifying strand and cross cutting themes. It should be noted at this stage the PSTs are not pushed to consider the overarching elements of framework e.g. principles, key skills and learning statements as when attempted previously it was observed that they felt overwhelmed and the intended outcomes of the session were diminished. This additional interlinking is introduced at a later stage when they have more confidence planning. In summary, the task has been well received by the PSTs. The key learnings observed include:

- Increased awareness of the specification
- Positive reflections on the use of group work. PSTs recognise the benefits of working in teams where each participant brings different discipline expertise and they feel that this strengthens their outcome. This is encouraging to see as there is a policy push to create more communities of practice within and across school departments.
- PSTs noted that they made more links than would have been possible working individually. During the task it is not unusual to hear PSTs saying, "I never made that connection before" or "that explains that concept better to me", or "I wish I would have learned it like this". They generally appear more able and willing to investigate how different contextual strands can be integrated.
- In discussions on the sequence design, PSTs have identified that the teaching approaches adopted in their plans need to align with the learning outcomes they have selected. They also begin to recognise that different outcomes can be developed using the same general tasks and that the instructional approach adopted drives the learning focus.

Example 3: Making Judgements

The final example relates to supporting PST to assess and make judgements on student work. The assessment of the new science specification requires more use of formative assessment and judging students work against rubrics which describe features of quality. It sees the introduction of new elements including classroom-based assessments on an extended experimental investigation (EEI) and on a science and society investigation (SSI). It also involves teachers collaborating and peer assessing work in Subject Learning and Assessment Reviews (SLARs). PSTs would not have engaged in such tasks previously and hence need a lot of support during their ITE education. To address this, they are given a sample of student work to review. The sample relates to student (13-14yrs) analyses of different articles and responses to questions relating to issues such as article quality, bias, validity of claims (identifying evidence), data retrieval and conceptual understanding. The PSTs have to assess three samples from different students and make judgements (with evidence) using the categories:

- Exceptional
- Ahead of expectations
- In line with expectations
- Yet to meet expectations.

These headings are selected as they relate to the those from the features of quality rubric used to evaluate the EEI and SSIs classroom-based assessments of the specification. The PSTs individually assess the student exemplars and then conduct peer reviews in small group settings where they discuss and justify their judgements. The extension of this task requires PSTs to design and peer critique assessment tasks and rubrics from lessons they have previously taught.

PSTs have actively engaged in this task. They have found it very challenging particularly as the samples of work provided require judgements to assess as opposed to assessments which include mathematical problems or factual recall questions that have clear correct or incorrect answers. It's not unusual to hear PSTs claim that '*this is assessing English not science*'. It has been observed that they struggle to distinguish between quality of writing and accuracy of answers in this context. They also point towards needing more specific criteria to make judgements. By the end of the task discussions generally veer towards the importance of evidence and how it's interesting that when assessing work, the teacher in many ways is adopting the same approach they are asking their students to adopt when making scientific claims. In this way they see parallels between the skills they need to assess student work and the skills which they are trying to develop within their students. This also leads to further parallels being made between skills required in science and those required in other discipline areas such as humanities-based subjects.

6. Conclusion

Opportunities and Challenges

It is the intention that the sample tasks presented have illustrated some of the key curricular reforms recently introduced at second level in Ireland, in relation to the general Junior Cycle framework perspective and more specifically to the new science specification. With these changes come both opportunities and challenges. It has been observed that PSTs struggle to deal with the ambition to develop key skills as well as adopting new pedagogical (*learning and assessment*) approaches in a more integrated curriculum which aims to develop the capacity of the learners to be active local and global citizens. It has also been noted that in some cases PSTs have explicitly noted that they feel they are only developing the skills that they are expected to teach such as critical analysis. While the PSTs personal teaching beliefs tend to align with those of the curriculum, they are unsure how to incorporate these aspects into their lessons as they have may not have experienced them as learners. Given this uncertainty PST can become overwhelmed and hence see these aspects as add-ons which they don't feel they have time to develop. This can generate tensions between their personal philosophies as science teachers and their perceived pressures of 'getting through' the curriculum. The resulting effect is that their teaching practice does not reflect their personal beliefs or the those being advocated at a policy level.

It is argued that while complex these challenges can start to be addressed at ITE level. It is proposed that the three pillars approach of modelling, reflection and application is a valid approach to eliciting and developing PSTs skills and pedagogical strategies. It is also contended that when preparing PSTs, it is imperative that TEs focus on empowering future teachers, not just for current curricular and policy changes, but to be able to adapt their teaching throughout their career to the needs of learners and society. It is maintained that developing PSTs as reflective practitioners and collaborators is fundamental to achieving this.

Thoughts for the future

It is acknowledged that policy and curricular reform take time to be integrated into an education system and indeed there are situations where this reform is not successful. It is felt that while full stakeholder engagement is important to this success it is fundamentally necessary to recognise that teachers are key to unlocking innovation and reform. The role of the teacher in the context of recent reform and the need to prepare learners for an ever and fast changing society is increasingly complex. As a consequence, there are implications for ITE. There are challenges to use strategies to both identify and develop skills that teachers are expected to promote in their teaching. It is argued that incorporating three pillars, modelling, reflection and application is one such approach. It is felt that this develops teacher's stance towards empowerment and becoming reflective practitioners. Finally, it is suggested that ITE is only one part of the picture and that explicit frameworks for teacher professional learning which are based on teacher empowerment and teacher professional reflection are key to successful curricular and policy reform that ultimately supports learners to become effective citizens in a changing society.

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References

Department of Education and Skills (2015a). *Framework for Junior Cycle 2015.* Dublin. https://www.education.ie/en/Publications/Policy-Reports/Framework-for-Junior-Cycle-2015.pdf

Department of Education and Skills (2015b). *Digital Strategy for Schools 2015 – 2020: Enhancing Teaching, Learning and Assessment.* https://www.education.ie/en/Publications/Policy-Reports/Digital-Strategy-for-Schools-2015-2020.pdf 37

Department of Education and Skills, National Council for Curriculum and Assessment (2015). *Junior Cycle Science: curriculum specification*. Retrieved June 2019, from https://www.curriculumonline.ie/Junior-cycle/Junior-Cycle-Subjects/Science

Department of Education and Skills (2017a) *STEM Education: Policy Statement 2017 – 2026* https://www.education.ie/en/The-Education-System/STEM-Education-Policy/stem-education-policy-statement-2017-2026-.pdf

Department of Education and Skills (2017b) *Action Plan for Education 2017* Action Plan for Education 2017 https://www.education.ie/en/publications/corporate-reports/strategy-statement/action-plan-for-education-2017.pdf

Initial-Teacher-Education-Criteria-and-Guidelines-for-Programme-Providers.Pdf. https://www.teachingcouncil.ie/en/Publications/Teacher-Education/Initial-Teacher-Education-Criteria-and-Guidelines-for-Programme-Providers.pdf

Irish National Framework for Qualifications, https://nfq.qqi.ie/

McComas, W.F. The many reasons we teach science and what everyone should know about how it works, 2010, Establish and SMEC Conference, Dublin

McComas, W.F. (Educating Science Critics, Connoisseurs and Creators What Gifted Students Must Know about How Science Functions *Gifted Education Communicator* Fall 2010, Vol. 41 No. 3

Middle School • Fungi and Life Processes • Legacy Series | AST. https://ambitiousscienceteaching.org/middle-school-%e2%80%a2-fungi-life-processes-%e2%80%a2-legacy-series/

Report-Rocard-on-Science-Education_en.Pdf. https://ec.europa.eu/research/science-society/document_library/pdf_06/report-rocard-on-science-education_en.pdf

Rethinking Education: Towards a Global Common Good? – UNESCO 2015 Digital Library. https://unesdoc.unesco.org/ark:/48223/pf0000232555

SDGs: Sustainable Development Knowledge Platform https://sustainabledevelopment.un.org/sdgs

Specification-for-Junior-Cycle-Science.Pdf. https://www.curriculumonline.ie/getmedia/f668d804-6283-4d4a-84ab-c71e5b37d198/Specification-for-Junior-Cycle-Science.pdf

World Economic Form. https://www.weforum.org/focus/fourth-industrial-revolution.