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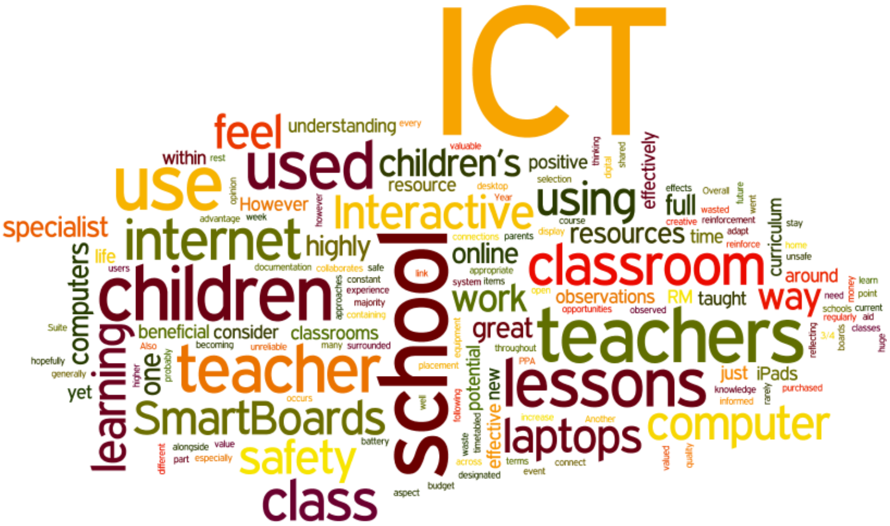
FICTION: A Literature Review of Methodologies and Strategies Related to the Introduction of ICT in Schools for Teaching Science



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Abstract

In order to create a sustainable digital society, national governments are creating strategies where schools play a central role in the increase of digital competence among citizens. Schools should be the leaders in exploiting the potential of information and communication technology (ICT) in the best way to achieve high digital skills among students. To accomplish this, many countries have recently implemented digital knowledge/digital competence as an important part of their school curricula. Digital tools are understood to enable new opportunities to increase students' understanding, as these tools can, e.g., be used to visualize concepts and processes in a more accessible way. This in turn is understood to have impact on students' development and learning.

The FICTION project identifies science subjects as good examples where digital tools can increase students' understanding by visualizing abstract models and theories. For this purpose, the further development of teachers' digital competence is the most important need to be addressed. The project presented in this paper aims to enhance teachers' abilities to teach students to use digital tools for their own understanding of science, and to identify weaknesses and strengths in digital tools for teaching. The understanding of how and why digital tools are used increases knowledge among teachers for further professional development, necessary for future professional needs.

Keywords: *professional development, ICT, literature review*

1 Introduction

1.1 Introduction

Many countries have recently implemented digital competence as an important part of their school curriculum. One example of this is Sweden, where the curriculum today states that: "Teaching should give students the opportunity to use digital tools in a way which promotes knowledge development" [56]. With this addition to the curriculum, digital tools in teaching and learning have become mandatory to implement. These changes pose new challenges for schools and teachers. For example, schools need to assist with infrastructure and make technology available, and teachers need to acquire knowledge on how to use the technology for educational purposes.

Although technology use increases in educational settings [9], digital technology integration is still considered to be a complex process of educational change [21]. Several different barriers that teachers encounter when integrating digital technology in the curricula have been presented in earlier research [30, 42, 63]**.** But, just as there is research that points to difficulties in integration, there is also research that presents driving factors. One example is the study by Perrotta [77], which shows a clear connection between teachers' perception of school management's support in digital technology education and their perception of usability. Furthermore, the school culture affects teachers' experiences and expectations on the use of ICT technology, perhaps even more than what the teachers' personal qualities, such as age, gender and teaching experience, do. In a study by Drossel, Eickelmann and Schulz-Zander [26], they identified the supporting factors were school characteristics, teachers' attitudes, teacher collaboration and background characteristics. The study also concluded that collaboration between teachers constituted an important predictor for the successful implementation of digital media in schools and teaching. This finding is also supported by Li, Yamaguchi and Takada in their study of factors affecting primary school teachers' use of information and communication technology (ICT) in student-centred education [14].

Achieving the goal of digital technology integration to support teaching and learning in the classroom has thus in several studies been argued to be influenced by teachers' attitudes and pedagogical beliefs. It has also been suggested that one needs to examine the link between teachers' pedagogical beliefs and their practice to fully understand the integration [31, 83, 89, 106].

Calling on more research on teachers' pedagogical beliefs in connection to ICT use, Ertmer et al. [32] presented a conceptual overview of teacher pedagogical beliefs as an initial step towards understanding more about these issues. While highlighting how important it is to take the teacher beliefs into account, Ertmer and colleagues say: *"When considering ways to change teachers' practice, particularly their uses of technology, the literature reviewed here suggests that is impossible to overestimate the influence of teachers' beliefs."* The challenge thereby becomes to find effective ways to alter the already existing images of what is proper and possible in the classroom setting. A follow-up study [5] revisits the question about the teachers' pedagogical beliefs and their impact on ICT use. The results from this study show that *"teachers' own beliefs and attitudes about the relevance of technology to students' learning were perceived as having the biggest impact on their success."*.

With the revision of the school curriculum, and based on earlier research highlighting the teachers as an important driver for integration of digital technology, it becomes important to examine how teachers' teach students to use digital tools for their own understanding of science, and how the teachers develop their knowledge related to meaningful digital technology use.

1.2 Background

1.2.1 Digital competence in the school curriculum

The European Commission has listed eight key competences for lifelong learning, which applies to all members in the European Union, and one of these are *digital competence* [36]. Digital competence is understood to include *"the confident, critical and responsible use of, and engagement with, digital technologies for learning, at work, and for participation in society."* The term is broad and inclusive, and also refers to information and data literacy, media literacy, communication, intellectual property related questions and critical thinking etc. [36]. Being one of the key competencies, educational establishments have been commissioned to increase and improve the level of digital competence at all stages of education. This includes "*...promoting a variety of learning approaches and environments, including the adequate use of digital technologies in education, training and learning settings…"* The European Commission acknowledging of digital competence and the importance of investing in these skills, has been seen as a first step towards fostering education in Europe and in a world where digital technology develops fast.

The European Framework for the Digital Competence of Educators (DigCompEdu) set out to explore educators need of digital competences [86]. The starting point is the assumption that teachers *"require*

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both broader and more sophisticated set of competences than before". Calling awareness upon the combination of the digital tools and the requirements for teachers to help students become more digitally competent. DigCompEdu offers a framework directed towards educators, but also it aims to guide policies and to provide a common language and approach to the concept of digital competence in the school setting.

As a member state of the EU, Sweden has implemented digital competence as an important part of their school curriculum. The Curriculum for compulsory school was revised 2016 with the addition of "digital competence" in the overall goals and core content of all subjects, e.g.: "Teaching should give students the opportunity to use digital tools in a way which promotes knowledge development" [16].

The term *digitalisation* encompasses the whole process of having more teaching methods based on digital technology. That being said, our understanding of the term is broad and includes both knowledge of skills, knowledge about the context, and consequences of technology integration in schools. It also includes both the teacher and the students' perspective.

1.2.2 Purpose of the FICTION project

By acknowledging digital competence and revising the school curriculum Sweden [16] has agreed on implementing changes in the education system. The responsibility of the teachers is to improve education accordingly, meanwhile the teachers are expected to be supported in their tasks by their school.

"Teachers need to leave their teacher preparation programs with a solid understanding of how to use technology to support learning. Effective use of technology is not an optional add-on or a skill that we simply can expect teachers to pick up once they get into the classroom. Teachers need to know how to use technology to realize each state's learning standards from day one." [19].

To address the aforementioned needs the FICTION project aims to:

- Identify weaknesses and strengths in the use of digital tools for learning,
- enhance science teachers continued skill and knowledge development over time regarding use of digital tools and how these tools can support learning,
- enable continuous knowledge dissemination between science teachers.

To meet the project's goals science teachers from three countries (Sweden, Italy, and Ireland) have been involved in the study.

1.3 Theoretical assumptions

1.3.1 E-learning

Earlier research on educational technology (E-learning) has included digital technology but often focused on the processes and procedures when integrating digital technology into education [102]. Through mapping trends in the field of e-learning Hung [45] concluded that a shift in focus has occurred 2000–2008, from issues related to efficiency towards teaching and learning practices. However, Hung emphasizes that there are differences between countries in adoption of e-learning practice. What we can see today, is that

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digital tools also are understood to enable new dimensions in learning, for example additional understanding of concepts and processes. This can be done by enabling faster feedback to the student or using response tools during the lessons [17]. This has resulted in an emphasis on digital didactic thinking and shift in teaching practices from planning for teaching to planning for learning [14]. Further, this leads to a focus on the student as creator of their own knowledge, and the teachers as creator of different learning situations.

1.3.2 Science teaching and digital tools

1.3.3 Teachers' perspectives on ICT

Although the conditions for successful technology integration, such as better hardware and software, there is still relatively low use of high-level digital technology in the school setting [8,9]. In addition, for the students to benefit from digital technology use, teachers need to be able to use the same technology helping students to learn. Furthermore, these technologies are unlikely to be used unless they fit with teachers' existing pedagogical beliefs [4]. Calling on more research on teachers' pedagogical beliefs in connection to ICT use, Ertmer presented a conceptual overview of teacher pedagogical beliefs as an initial step towards understanding more about these issues. While highlighting how important it is to take the teachers' beliefs into account Ertmer says: *"When considering ways to change teachers' practice, particularly their uses of technology, the literature reviewed here suggests that is impossible to overestimate the influence of teachers' beliefs."* The challenge thereby becomes to find effective ways to alter the already existing images of what is proper and possible in classroom settings. A follow-up study [5] revisits the question about teachers' pedagogical beliefs and their impact on ICT use. The results from this study show that; *"Results suggest close alignment; that is student-centered beliefs undergirded student-centered practices (authenticity, student choice, collaboration). Moreover, teachers with student-centered beliefs tended to enact student-centered curricula despite technological, administrative, or assessment barriers. Teachers' own beliefs and attitudes about the relevance of technology to students' learning were perceived as having the biggest impact on their success."*

Several important factors for how the teachers implement and use technology in education have been discovered in earlier research. Drossel et al. [26] emphasize factors such as the degree of collaboration between colleagues, the teachers' self-confidence in the use of digital tools, and the teachers' attitudes towards the use of technologies in education [2]. The authors argue that teachers' perceptions of whether IT promotes knowledge development determines whether digital tools are used or not in the classroom. They further suggest that understanding the teachers' attitudes towards IT is important for a successful implementation of digital tools aimed at improving student results. In other words, the teachers are key figures in the implementation process. This view is also reported by Tallvid who emphasizes that teachers are the ones who need to realize the objective, even when the initiatives most often come from school leaders or policymakers [18].

1.3.4 Professional development

The implementation of digital competence in the curriculum, with its broad definition, highlights the need for teachers to constantly adapt to a changing world. To be able to keep up with technology, and to translate their subject knowledge so that digital tools become part of the practice of conveying this knowledge, requires constant development. Arguments have been presented by earlier research that both local conditions and global components need to be considered to achieve effective practice when it comes to teachers' professional development (TPD) [2].

While aiming to synthesize key issues and challenges for TPD, Albion et al. [2] present a study which incorporates four different cases. Based on the results the authors suggest a conceptual model for identifying and evaluating TDP practices to facilitate ICT as a lever for educational change. The study clearly indicate the "importance of TPD as a means of clarifying beliefs, vision and action regarding ICT integration in teaching and learning". The model of TPD for technology-enabled learning presented by Albion and colleagues derives from three main foci and is based on a literature analysis. The three main foci, or elements are: shared vision for ICT, networks & communities and design-based research. The foundations for these three are enabling conditions such as access to ICT, curriculum, time etc. The three elements are described to be in a complex reciprocal relationship with TPD. This means that there is an interdependence between the various factors and how they affect the use of ICT in schools. For example, the shared vision of how ICT could be used to support learning among the teachers may both be developed through TPD but will also influence the content of TPD.

The general understanding of the importance of digital technology integration in education has already resulted in several countries providing professional development for teachers [2]. However, there are studies reporting on teachers' experience of inadequate training in using digital tools in teaching and nothing about how to use them in an effective and meaningful way [15].

1.3.5 Participatory design

Designing computer systems in order to achieve *usability* for the intended users [51] requires considering not only the functionality of the system itself but the entire *user experience* of understanding what needs the system fulfills, learning how to use it, and the actual interaction with the user interface.

Participatory design includes (representatives of) the end users as active participants in a system development process along with user experience designers [25, 81, 94], thus ensuring that the end users' concerns and requirements are considered in the design process. Giving users control over their work environment can be considered a worthwhile goal in itself, but their involvement in the development process also increases "buy-in" by the user community, maximising uptake of any new work methods required.

1.4 Community of practice

With roots in the concept of community of inquiry, but also in learning through occupation, Lave & Wenger [58] proposed the concept of *Community of Practice* (CoP). Initially they studied how learning outside the classroom occured, and formulated the term to describe learning through practice and participation (initially named situated learning). Communities of practice are described as continually intertwining processes of 'participation and reification' [117], and the structure of CoP consists of three interrelated terms: mutual engagement, joint enterprise and shared repertoire [116].

Using this approach to understand how we can best achieve and meet the FICTION project goals will provide insight both in the participating teachers' practices and their collective experiences accomplished through participation in their particular communities.

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Communities of practice are formed by people who engage in the processes of collective learning in a shared domain [58], in this case CoP should be understood as a group of people who are active practitioners and where membership is dependent on their shared understanding, with the purpose to share best practices and provide support for each other.

2 National policies

2.1 Ireland

Since 1998, the Department of Education and Skills in Ireland has actively pursued the integration of ICT into teaching and learning all subjects including science and the development of pupils' digital literacy, primarily through its 'ICT in Schools Programme', which has focused on four key areas:

- The provision of essential ICT infrastructure within schools
- The provision of access to broadband connectivity to schools
- Continuous professional development for teachers in ICT
- Integrating ICT within the curriculum and providing curriculum-relevant digital content and software. [47]

The Department of Education and Skills has published and started the implementation of the 'Digital Strategy for Schools (2015-2020) – Enhancing Teaching, Learning and Assessment', which aimed to enable stakeholders to support the integration of ICT in every classroom in a systematic and focused way, underpinned by the theory that ICT is a powerful tool that can change the way teachers teach and how students learn. [120]

The Strategy was developed using an evidence-based approach. Base line data on the usage of ICT by teachers and schools was gathered in a Census Report. [17] This research was collated and resulted in publication of a consultative paper, 'Building Towards a Learning Society: A National Digital Strategy for Schools (2013)'. [12] The publication of the consultative paper coincided with the launch of a public consultation phase. Some one hundred and twenty-four submissions on the content of the consultative paper were received from a variety of organizations and individuals. In addition, there were face-to-face meetings with stakeholder groups, including young people.

The result of the consultative phase in combination with research on the integration of ICT at international level was the formulation of the Strategy document. The lynch-pin of the Strategy is that ICT should not be peripheral to teaching, learning and assessment but a key component of a high-quality twenty-first century education system and that meaningful integration of ICT is the responsibility of all stakeholders.

The Census Report identified four key themes around which the Strategy was developed: Teaching, Learning and Assessment Using ICT; Teacher Professional Learning; Leadership, Research and Policy; ICT Infrastructure.

Some key priorities of the Strategy during the implementation phase have been:

- To give teachers and schools clarity around the concept of embedding ICT into Teaching Learning and Assessment, through adapting and localizing the UNESCO ICT Competency Framework for Teaching for the Irish context. This identified training needs to be targeted by the Department and its support services which resulted in a Digital Learning Framework for Schools. [23]
- To reflect technological and educational developments through updating the 'eLearning in Your School' planning resource (from 2009) to assist schools in further developing their eLearning policy.

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- To address the ICT infrastructural requirements of schools through developing an ICT Equipment grant, continuing to improve broadband services to schools.
- To promote Scoilnet and associated sites/services as the national reference point for schools for high quality digital content. [91] Scoilnet is an education website containing a database of 15,000+ online resources, including websites, quizzes, lesson plans, notes, video/audio, games and other multimedia, which teachers can use to enhance their classes. The aim of this is:
  - To provide information to teachers on innovative ways to use digital technologies more actively in their own teaching, including exemplars of good practices, and facilitating the sharing of such practices amongst teachers.
  - To enhance access to and impact of Continuous Professional Development (CPD) for teachers through extending CPD delivery formats to include online and blended learning programmes.·
  - To explore and recommend technical support solutions for schools.
  - To extend the scope and reach of student learning beyond the walls of the classrooms.

In 2017, a detailed Digital Strategy Action Plan was published, outlining over 120 actions and sub-actions to be implemented during 2017 by the Department, its agencies and others across government. [120] Timelines and lead responsibility were assigned, and progress was measured against the plan. Of the actions, 113 were delivered representing a 94% completion rate.

A follow on detailed Digital Strategy Action Plan was published for 2018. [121] This Plan had over 80 actions, and set out a roadmap for 2018, to bring the Irish education system further along the path to becoming the best in Europe at embedding digital technology in teaching, learning and assessment by 2026. 2019 and 2020 should see further action plans to build on the successes of the previous plans.

Key elements of the 2018 Digital Strategy Action Plan include:

- Computer Science has been introduced as a Leaving Certificate subject from September 2018 – (phased introduction).
- The National Council for Curriculum and Assessment (NCCA) will work with a network of schools to explore how coding might be best integrated into the primary school curriculum.
- The Digital Learning Framework, which allows schools to assess their digital capability, will be assessed and improved.
- Clear statements on the use of digital technologies will continue to be included in all the subject specifications developed in 2018.
- Clusters participating in School Excellence Fund – Digital will begin their projects & future rounds will be considered.
- The Department will actively contribute to the whole of Government approach to internet and cyber safe security for our young people.
- A circular will issue to schools on the usage of smartphone and tablet devices – this will require schools to engage with the school community including students and parents on their usage.
- Continue to improve broadband services in schools.

In March 2019 the Minister for Education announced the third year of funding a further €50 million investment in ICT infrastructure for all primary and post-primary schools bringing the total spend on Digital Strategy for Schools ICT Infrastructure Fund to €110m. On application, all eligible schools will receive grants to purchase key technology including tablets, cloud systems, learning platforms and projectors to enable them to embed the use of digital technology in teaching and learning. The Minister said, “We are living in a world which is being fundamentally transformed by digital technology. Disruptive technologies in cloud, mobile and social are revolutionizing how we work and how we live. Critical, creative thinking, problem solving skills and adaptability will be key to ensuring young people flourish in this environment and we need to make sure they are well prepared. This investment in effective ICT infrastructure in schools will also support curriculum development and enhance teaching and learning”.

The Department has also ensured that schools receive advice and support for various elements of implementation of the Strategy, for example:

- Appropriate equipment and technology—available from the PDST Technology in Education website. [75] PDST Technology in Education is part of the national support service, Professional Development Service for Teachers, and operates under the aegis of the Department of Education and Skills. It promotes and supports the integration of ICT in teaching and learning in first and second level schools.
- Procurement related issues - available from the Schools Procurement Unit Website. [103]
- A Digital Learning Framework rolled out nationally from September 2018 to assist schools in their efforts to embed the use of digital technologies in teaching, learning and assessment. Reflecting that Framework, and other developments in the sector, an updated resource for e-learning planning has also been made available to schools to assist in developing and enhancing schools’ Digital Learning Plans, called Digital Learning Planning Guidelines. [84]
- The Webwise programme is an internet safety initiative funded by this Department and the EU Safer Internet Project and it has important connections with other relevant Government Departments and agencies and the National Parents Council. [113] It provides access to information on the latest technologies and the changing use of social media.

The Professional Development Service for Teachers (PDST) - Technology in Education is part of the national support service and operates under the aegis of the Department of Education and Skills. promotes and supports the integration of ICT in teaching and learning in first and second level schools. In 2016, as part of the PDST Technology in Education, 5,800 teachers (primary and post-primary) received ICT training.

In conclusion, the updating of curricula at primary and secondary levels has changed the focus from traditional didactic teaching to active learning and investigative student-centric approaches. The potential for ICT is summarized in the STEM Education Report (2016): Technology-facilitated education has the potential to transform traditional science and mathematics classrooms from a teacher-directed model to a facilitatory or constructivist model where the teacher is supporting and co-constructing personalized teaching and learning experiences for the learners, both individually and collaboratively. [104][13] The Report identified several requirements to achieve its Vision for STEM Education in Ireland, including: Supporting the introduction of digital technology to facilitate international collaboration in STEM subjects between schools, and between schools and research facilities (e.g. remote telescopes, remote laboratories); and developing a suite of ‘Technology-Enhanced Learning’ (TEL) CPD programmes in STEM disciplines for teachers at primary and post-primary levels. These and other initiatives will provide students in Ireland with STEM education experience of the highest international quality; this provision should underpin high levels of student engagement, enjoyment, and excellent performance in STEM disciplines.

2.2 Italy

2.2.1 1980–1985: the pioneering phase

With the exception of the technical and professional computer courses already in place since 1967, the first computers began to be introduced in schools in the early 1980s with the first marketing and dissemination of personal computers.

At the same time, on a strictly local basis, the first computer literacy courses are organized, attended by a fair number of teachers, especially in technical-scientific subjects.

These courses are aimed at understanding what a computer is, its internal structure, its operating system, the way in which a program can be realized by means of a programming language (in general Basic).

In this period, the research centers that have developed a background of skills related to the application of the computer in teaching and that can be a reference for the introduction of new technologies in schools are very limited, in particular, we remember the Institute for Educational Technologies (ITD) [52] of the CNR of Genoa, which, since the 1970s, has contributed significantly to founding in Italy the field of research on educational and teaching technologies.

In 1985 ITD founded the first Italian library of educational software, which collects and makes available for viewing the various software packages (especially in English) that were developed in those years. These are almost exclusively tutorial and exercise programmes.

Tutorial programs are real courses on topics of a discipline, very often of a scientific nature, carried out according to the principles of programmed education and Computer Aided Instruction (CAI).

The presence in schools of computers with different operating systems, often incompatible with the various packages available, the “poverty” of the software (no graphics, very limited interactivity) meant that these products had in those years a low impact on the school system.

2.2.2 1986–1990: the first National ICT Plan

In 1985 the first national programme in the field of new technologies was launched in Italy: the Piano Nazionale Informatica (PNI1) [6, 122], aimed mainly at mathematics and physics teachers in high school. The aim of this plan is to develop basic computer skills in teachers so that they are able to cope with the changes in teaching programs that are beginning in this period to propose, on an experimental basis, mainly in mathematics and physics.

The PNI1 provides for the training of about 20,000 teachers and the creation of 7,000 computer structures in as many high schools. At the basis of the realization of the PNI1 there is the idea that information technology, with its methods and languages, can be the gateway to enter the information society that has developed in recent years.

It is also believed that the use of concepts, methods, tools and techniques specific to information technology can contribute, on the one hand, to the cognitive development of students and, on the other, to the profound renewal of teaching programmes and, in particular, of mathematics and physics.

In recent years, no national initiatives similar to those of PNI1 have been promoted in compulsory schooling. However, even in these schools a variety of initiatives are being developed and multiplied, both at local level and coordinated at national level, aimed at introducing computers into school activities.

The project coordinated at national level that has a strong impact on the level of educational design is the IRIS project (Initiatives and Research for Information Technology in the School), promoted by the CEDE of

Frascati. This project involves primary and secondary school teachers (especially in mathematics and technical education) in the design of pathways and teaching materials to be tested in the classroom. The project aims to initiate students to a conscious use of the computer, making them understand the links between the science of information and other fields of human culture, especially the scientific-mathematical.

In recent years, the enhancement of hardware and the development of operating systems based on direct manipulation interfaces leads to a rapid evolution of both professional and educational software. Teachers from many disciplines in technical and vocational schools are beginning to integrate the use of professional software packages for their field of study (office automation systems, CAD systems, systems for circuit design and simulation of their operation) into the development of the contents of the various professionalizing technical subjects.

In the other subjects of teaching, both professional software and educational software of a different nature from those available up to that moment (i.e. tutorials and drill & practice) are beginning to be used. All school levels and disciplines are beginning to be affected by curriculum changes through the use of professional software, such as word processors, spreadsheets, data processing programs.

The new educational software made available by the technological evolution are the systems based on micro-worlds and the systems of simulation of phenomena.

2.2.3 1990–1995: the second National ICT Plan

In 1991 the National Computer Science Plan, with the name PNI2, was extended to the disciplines of the linguistic-literary area of high school. With PNI2 in-service teacher training is more oriented towards a targeted approach to the use and application of ICT, and not just the introduction of basic IT elements into school curricula. Its aim is to promote the use of computer tools in schools and to promote an integrated didactic and training design mediated by the use of such tools. The PNI2 radically changes the perspective with which to look at the use of the computer in teaching practice. The focus is no longer on the computer, on the understanding of its internal functioning logic, on the development of programming techniques and their possible integration into the curriculum of some discipline, but on the content of the teaching activity and the conceptual aspects that characterize it. At the same time, models are tested for the use of computer resources (professional application software, educational software, software for the construction of hypertexts, the first telematic systems) capable of innovating and improving teaching practice through an approach centred on the creation of products by students (newspapers, data archives, reports, multi-handed work, etc.).

This change of direction in the National IT Plan is largely due to the evolution of the hardware and software available on the market, which make possible new models of use of ICT in education. Two new types of didactic practices characterize, in fact, this five-year period compared to the two previous ones: the didactic practices of hypertext construction and the first experiences centered on the use of telematic systems.

2.2.4 1995–2000: the Educational Technology Development Programme

In 1997 the MPI launched the Educational Technology Development Programme (Programma di Sviluppo delle Tecnologie Didattiche, PSTD, 1997–2000) [48]. This program insists on the concepts of multimedia and networking, which should have been part of the teaching of every teacher at every level of school, starting from kindergarten.

The PSTD is divided into different types of projects and more specifically:

· General projects:

- Project 1(a) for the provision of operational units for teacher training;

- Project 1(b) for the endowment of operational units aimed at the development of educational practices based on the use of multimedia with the classes.

· Special projects aimed at supporting general projects and intervening with additional resources to broaden the innovative processes underway. The first special project finalized concerns the teaching of foreign language in primary school supported by the use of multimedia tools.

· Pilot projects, aimed at testing innovative advanced teaching solutions in a limited number of schools in order to guide future developments. The pilot projects were numerous and addressed various aspects of educational innovation through the use of ICT (Multilab Project, Network Project, Polaris Project, etc.).

In these years the evolution of the software makes available new multimedia software, of good quality, that are used in the classes as support material on CD for the didactic activity. For example, the publishing industry is beginning to provide various multimedia programs for learning a second language, which have a high level of hypermedia (integration of text, graphics, audio, video) and interactivity. These programs are also used in the finalized projects of the PSTD.

These years are also characterized as the years of the spread of the Internet in schools. Websites and email services for teachers are starting to multiply. The first didactic uses of the network are developed, both as a tool for access to information and knowledge and as a tool for the development of cooperative activities in the network.

The network is also beginning to be used for the development of distance learning courses for in-service teachers, carried out according to new approaches based on the active participation of trainees and the reworking of their professional experience.

The network also becomes an important tool for actions supporting the process of school autonomy (Copernicus project [69], launched by the MPI in 1998) and for the development of educational projects related to the relationship between technology and science (National Project SeT [96], launched in 1999).

This latest project on science and technology education (SeT) was launched with the aim of encouraging the overall growth of scientific and technological culture in schools by improving the quality of teaching.

In particular, the schools participating in the project receive resources to:

- Improve the structures and the didactic organization of the scientific-technological teaching;
- Create services, support actions and training opportunities for teachers;
- Involve the various organisations involved in the development of science and technology: research institutes, museums, bodies and services for the protection of the environment and health, industrial enterprises.

In the methodological field, the project aims to overcome the separation, often clear, between scientific and technological disciplines through the interaction between the study of knowledge and practical-experimental activities, focusing on information and communication technologies, understood as new tools for science and technology education, giving, among other things, the opportunity to communicate and collaborate remotely, to search for information and management of education.

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2.2.5 2000–2006: the National Plan for the Training of Teachers on Information and Communication Technologies

Since 2000, the Ministry publishes several documents and guidelines relatively to the subject of ICT.

From the ministerial infrastructure objectives of 2002:

- provide all schools with fast Internet access by the end of 2002;
- to progressively link schools to research networks by the end of 2002;
- reach the ratio of 5–15 pupils per multimedia computer in 2004;
- ensure the availability of support services and educational resources on the Internet and prepare for electronic learning platforms for teachers, students and parents by the end of the at the end of 2002;
- the presence of no less than 50 to 60 computers per institute;
- the presence, inside the school, of computers aimed at providing services inside and outside the school.

In particular, at that time, the first large-scale action undertaken by the Ministry of Education to disseminate information technologies in primary and secondary education can be identified with the "National Plan for Teacher Education on Information and Communication Technologies (ForTic)" [67], implementing the decisions taken by the Council of Ministers by decree of 22 March 2001, as part of the Italian Action Plan for the Information Society, which in turn was a response to the recommendations given at European level with the e-Europe Action Plan launched in Lisbon in March 2000.

The project is divided into three types of training courses aimed at giving skills:

1. on the use of computers in teaching and school management
2. on coordination and guidance for the use of technological and multimedia resources in education
3. on the configuration and management of technological infrastructures in schools

The National Training Plan on the computer and technological skills of school staff is conceived as a multi-year intervention that allows to complete the training, thanks to the availability of online materials and the presence of competent figures within each school institution, to meet all the needs existing in the area of technology.

Specifically, the development of actions aimed at supporting the innovation process for primary and kindergarten teachers is identified as a priority, especially in view of the fewer opportunities they have had in the past.

The plan establishes 3 types of training courses:

- A Basic Training Course For Teachers With Little Or No Ict Skills. The training objectives see a competition of basic e-skills and ICT teaching skills.
- A training course aimed at creating a figure of teacher "consultant" expert in the methodologies and teaching resources offered by ICT. The training objectives are essentially oriented towards the problems of the didactic use of ICT, taking for granted, as a prerequisite, the possession by the teachers, selected as trainees, of the basic computer skills.
- A course aimed at building the necessary skills for a figure of "responsible" for the technological infrastructure of the school or networks of schools, The training objectives are oriented to skills of management of the technological infrastructure and presuppose, as a prerequisite, the possession of a fair familiarity with basic computer functions.

The ForTic project is developed in two editions, the first started in 2003 and the second in 2006 (ForTic2).

2.2.6 –2019: the National Digital School Plan

In 2007 the National Digital School Plan (PNSD) was launched [68] with the aim of promoting new practices and new organizational models, rethinking the learning space as a system open to the world. The plan involves the following main initiatives:

- The interactive whiteboard action, which provides funding for the purchase of interactive multimedia whiteboards and related training for teachers. With this action, 35,114 interactive whiteboards have been assigned and 72,357 teachers have been trained for both technical and educational use of the interactive whiteboards themselves;
- The Cl@ssi 2.0 action, with which classes are set up in which the use of technology is constant and widespread. Since 2009 and for the next three years, the project has involved 416 classes of every order and grade;
- The Digital School Publishing action launched in 2010, aimed at transferring teaching resources from paper to digital format, identifying among the benefits of the latter the possibility for students to edit, comment and interact with the text.

The Scuol@ 2.0 action, launched in 2011, allowed 14 schools to pursue a very advanced line of innovation, through strategies that combine innovation in educational planning with new models of organization of human resources and infrastructure of the school.

In summary, the 2008-2012 investment strategy aimed to bring digital into the classroom to address a large number of students, regardless of the disciplines covered.

In 2013 and 2014 further actions are launched, such as the wi-fi action for wireless connectivity in schools and the action Training Poles through which some educational institutions have been identified (so-called Training Poles) for the organization and management of digital training courses for teachers.

Law 107 of 13 July 2015 launches the second phase of the National Digital School Plan, divided into 4 steps: tools, skills, content, training, accompaniment. For each of them specific objectives and actions are identified, with the intent of not only looking at the technological element, but to propose a vision of innovation that involves students and staff at first hand.

The actions foreseen (35 in total) are organised in 9 working areas:

- access to provide all schools with the conditions for access to the information society, to ensure that the "Right to Internet" becomes a reality, starting at school, to cover the entire digital access chain of the school, to enable digital teaching (internal wiring of all schools, fiber for ultra-wideband);
- spaces and environments for learning with the aim, among other things, of transforming school laboratories into places for the encounter between knowledge and know-how, focusing on innovation, moving from teaching solely “transmissive” to active teaching, promoting flexible digital environments, rethinking the school as an educational interface open to the territory, within and beyond school buildings (active policies for the BYOD, mobile laboratories);
- digital identity, in order to associate a digital profile (unique) to each person in the school, in line with the integrated public system for digital identity management (SPID), reduce the complexity of access to digital services MIUR (a digital profile for each student and each teacher)

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- Digital administration, main objectives are to complete the digitization of school administration and education and reduce processes that use only paper, enhance digital services school-family-student (electronic register);
- students' competence, with the aim of defining a common matrix of competences to develop, support teachers in their role as facilitators of digital literacy.
- innovative didactic paths, innovate school curricula (bring computational thinking also into primary school);
- entrepreneurship and employment, to bridge the digital divide, both in terms of skills that occupy, promote careers in “STEAM”, enhance the relationship between school and work, involve students as a lever for digitization of businesses and as a driving force for vocations of the territories, promote creativity, entrepreneurship and the protagonism of students in the framework of the enhancement of key skills and for life within school curricula;
- digital content, with the aim of promoting open educational resources and self-production of educational content, and of upgrading school libraries as literacy environments for the use of digital information resources;
- staff training, centred on actions such as training for educational and organisational innovation at all levels (initial, in-service, in-service), technical assistance for first cycle schools;
- accompaniment, aimed at giving a territorial dimension to the PNSD through the creation of the figure of the digital animator in each school, supported by a team of teachers, properly trained, monitor the entire Plan and its implementation.

2.3 Sweden

The first attempt to address computer technology in schools by the Swedish parliament was in late 1960. This was followed in 1970 by some teachers, mostly in maths and science courses in compulsory school, offering students courses in computing. The 1980 Swedish syllabus for maths in compulsory school (lower secondary school) stated that students should “be informed about the use of computers in society”, they should learn to realize “that the computer is a technical tool that is controlled by people” and the functions of a computer should be addressed.

1984 parliament decided that all students in school should receive 80 hours of “computer science” teaching, defined as “teaching about, with and by computers”. For this the government granted 20 million crowns per year for three years for municipalities to buy computers for schools. During 1988–1991 computers started to be used for word processing in language teaching. Between 1984 and 1993 the government invested a total of 240 million crowns for the digitalization of the school. In addition, the municipalities financed the digitalization in school with the addition of 500 million crowns [87]. During 2010 several municipalities decided to introduce one-to-one computing when some schools bought portable computers for each student. The Swedish government decided in 2012 on the strategy “With the citizen in the centre—towards a digital collaborative management” where three overall goals were formulated: simpler everyday life for citizens, more open management to support innovation and participation, and higher quality and efficient operations. The Swedish government followed up with a strategy in 2017 for a sustainable digital Sweden that would contribute to competitiveness, full employment, and economically, socially and environmentally sustainable development. Sweden should be best in the world at using the possibilities of digitization. A report showed that 98% of Swedish citizens have access to the Internet at home and nine out of ten have smartphones [21].

In 2017 the Swedish government decided on a national strategy for the digitalisation of schools. This was urged by a report presented in 2016 by the National Union of Teachers in Sweden (LR) [56] in which the government, the Swedish National Agency for Education (Skolverket), and the universities were asked to take increased responsibility for digital development/ICT in schools. Since then the Swedish Association of Local Authorities and Regions (SKL) and the National Agency for Education have been responsible for the work on a national action plan. In this, the aim is for the whole school system to take advantage of the possibilities of digitalisation, and pupils and students should achieve a high digital competence. Also in the strategy, the process of digitalisation is explained to be more about driving change and less about technology [9].

One argument in the digital strategy was that all children and students in Swedish schools should have the same possibilities to develop digital competences for their future life and work. This was of importance since a survey of the access and use of digital tools among young people showed that the use was dependent on socioeconomic background, gender and demographic variability. [108] In line with the strategy, a change was done in the ordinance regulating the curriculum for compulsory school valid from July 1, 2018 [20, 109]. The revision is of importance as it promotes digital competence and places the responsibility on the schools to develop students' knowledge of the importance of digital competence and to form an understanding of the impact of digitalisation on the students themselves and on societal development. The ability to use digital tools were added to all syllabuses and in the syllabus of mathematics also students' knowledge in programming was included. As the revised regulation of the curriculum was only recently presented, the process of change and adaptation is in its initial phase.

The introduction of digital teaching in the curriculum presents new challenges for the schools. Above all, using digital technology has gone from being a voluntary teaching method to be a compulsory component in all activities. For example, it means that all schools have to acquire materials to meet the requirements and that all the staff at Swedish schools have been commissioned to implement digital tools in their teaching. It also states that it is the principal's responsibility to follow up the school's results and to ensure that teachers receive the skills training required to reach the national goals, including learning from each other and conducting a discussion to develop the education.

Skolverket makes available professional development courses in digital competence (among other things) [57] and Internetstiftelsen (the Internet Foundation) makes available teaching materials using digital tools [24].

2.4 Europe

The aim in Europe is that education will be transformed with new technology and open educational resources. Education should promote highly qualitative and innovative learning and teaching methods with new technology and a digital content. This will create a highly qualitative and efficient education that contributes to the goal of Europe 2020 to increase Europe's competitiveness and growth thanks to more qualified labor. It should also decrease the dropout rates in school and increase the number of students in higher education and give the chance for an effective and equal education. There are suggestions for how the EU member states can support this goal to support educational institutes to provide courses for teachers in computer skills and methods for learning, support the development and availability of open education resources, connect classrooms and provide digital equipment and digital content, to involve all stakeholders to implement the role of digital technology in educational establishments. The technology gives the opportunity for an effective and equal education. In addition, increased international collaboration is possible when education and knowledge can be moved across borders. Open technology gives opportunities to recruit new talent, to equip citizens with new skills, promote science and research and drive innovation, productivity, employment and growth. The European Commission will support digitalization through the Erasmus+ and Horizon 2020 programmes.

The European Commission has emphasised the Digital Education Action Plan on two priorities of digital competence: to improve the use of technology for teaching and learning and to develop digital skills for the digital transformation. Digital education involves the development of teachers and students learning in digital competences and the use of digital tools to support learning and teaching [35].
The use of the Internet in Europe has increased the last years. For example, 79% of European citizens are out on the net at least once a week. This is an increase of 3% during 2016. 78% of all European Internet users play games or download music, films, pictures or games [34].

3 Literature review

3.1 Review of the literature

We have surveyed the literature since 2015 to locate key articles on the use of ICT in teaching in each of the participating countries.

3.1.1 Barriers and enabling factors for the use of Tablet Computers

Young [119] carried out a study that examined the attitudes of teachers towards using tablet computers, predominantly Apple's iPad, across 22 post primary-schools in Ireland. The study also questioned some previous research and assumptions on the educational use of tablet computers. The study collected data from 259 out of 670 teachers across all sites using baseline and follow-up questionnaires. The teachers identified their barriers to technology usage as well as enabling factors; an overlap in barriers and enabling factors relating to professional development and the availability of time presents pathways for improvement. The study shows that given appropriate support, teachers possess (or can develop) a disposition towards creating new technology-enhanced pedagogies and relevant technological skills.

Not all schools supply the pupils with computers 1:1, so the use of ICT in teaching is dependent on the pupils bringing in their own devices, laptops or, more commonly, mobile phones. This causes a number of issues with equality in school, as well as technical problems of dissimilar platforms, installation and support. Sugliano [101] points out the contradictory legislation in many countries, where on the one hand, mobile phones are being banned in the classroom, while at the same time increased use of ICT tools for teaching and learning is required. (This is not to say that student distraction due to mobile phones is not a valid concern.) Sugliano proposes a solution to the BYOD (Bring Your Own Device) problem, addressing the technical, organisational, and methodological issues. This has been implemented at Liguria Digitale and

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consists of a network internal to the school, connected to the Internet through a firewall, with malware detection, content filtering, etc. The configuration of this setup is made available to others to copy at their local schools. The organisational part is handled by a Policy for Acceptable Use, which all users have to accept and sign. A key decision here has been to designate the school network as to be used only during school hours and only for school activities. The ongoing development by the teachers of best practices for BYOD in the classroom is essential for minimising the workload.

3.1.2 Flipped classrooms and blended learning

Pedagogical inventions that require ICT tools are flipped classrooms—where students are expected to study videos and perform interactive exercises in order to prepare for teacher-led lessons—and blended learning—where learning in the classroom is interspersed with online lessons, exercises, and tests.

Cozza and Scola [18] present a range of web-based tools useful for implementing flipped classrooms, for each step in the process: lesson planning, teacher tools, student tools, teaching tools, production tools, and evaluation tools.

Muciaccia et al [71] present the use of the open-source e-learning platform Moodle [70] for Inquiry-Based Science Education in a blended learning biology course. The co-writing tools of Moodle let the students work jointly on preparing and discussing material. The authors underline the need to let the students take their time to assimilate the material, ICT tools do not necessarily speed up learning. They further note that an important obstacle to the effective use of blended learning, at least in Italy, is the lack of digital competence by both teachers and students.

Crotty et al [19] describe how the Centre for Innovation and Workplace Learning, a research centre at Dublin City University, has been working with EU project partners on the Inspiring Science Education (ISE) Project [49]. The aim of the project is to build a large community of practice with digital and other resources to enhance teaching and learning of STEM subjects. The authors describe how webinars are being used to support a group of ISE Science teachers to integrate Inquiry Based Learning with the support of e-tools and resources into their repertoire of classroom strategies.

3.1.3 Proposing the integration of ICT in Mathematics Teaching and Learning – conclusions from PISA Reports

Perkins and Shiel [76] have concluded that there are potential benefits to extending the use of computers in mathematics classes in terms of deepening students' understanding of key concepts and processes. Their analysis of PISA reports has a number of conclusions as to how current progress on implementing ICTs into teaching and learning mathematics can be built on: by ensuring that, in addition to observing teacher-led demonstrations of mathematics processes using ICTs, students should have an opportunity to use ICTs on an ongoing basis in their mathematics classes, whether in classrooms or in computer rooms; using technologies in mathematics classes to support students in acquiring not only basic procedures but also higher-level processes; ensuring that, over time, students are exposed to a range of technologies in mathematics classes . These technologies could include: Dynamic geometry software, software to enhance statistical reasoning, internet applications, computer algebra systems, graphics calculators. Many of these technologies could also be used in science classes.

3.1.4 Using Video to promote Inquiry-based learning in science: the case of Logger Pro®

English et al [29] advocate integration of video and particular ICT software to enhance teaching and learning, as well as integration of, physics and mathematics. Their work is based on research that suggests that real world data simulations promote problem solving amongst students, peer-to-peer active engagement and higher order thinking [99]. Russell and Weaver [88] suggested that new approaches to the laboratory may be appropriate, in addition to efforts to improve instructor-student communication. This led to the development of a lesson which leverages a video analysis software for processing real world data such as the motion of a basketball in terms of physics and mathematical concepts. They describe an approach to unifying the constructs of building a bridge between concepts of mathematics and physics that is also economical in terms of equipment required—a webcam, or digital camera, and a computer to run the software Logger Pro®. They observed greater engagement and relevance for the students, and economy of preparation time for the teacher. Many other researchers have investigated the use of data logging to enhance laboratory science activities.

3.1.5 Review of Virtual Labs as emerging technologies for teaching STEM subjects

Lynch and Ghergulescu [64] present a review of available virtual labs, which they conclude have the potential to provide all students with practical experience in STEM subjects, while reducing the costs and minimizing the hazards associated with real labs. Ethical issues in biology and medicine, for example, have been abolished thanks to virtual labs. Virtual labs are not tied to geographical locations or time-limitations, and resources can be shared online between different organizations and institutions. They acknowledge that while there have been concerns regarding the effectiveness and realism of virtual labs, recent research has provided us with the tools to overcome these challenges, bridging the gap between real labs and virtual labs. Several studies have shown the positive impact of virtual and augmented reality, gamification and virtual worlds on students' learning, and all of these will be incorporated into the NEWTON virtual labs described in their paper.

3.1.6 Teachers' digital competence development through apps and digital stories about biodiversity

Nancovska Serbec et al in the TEALEAF (Teaching Ecology Through Apps – Learning Engagement and Fun) academic book [54], describe an Erasmus+ project research study that involved teachers from Ireland and other EU countries. This book summarizes a project that promoted digital competences in participating teachers. The teachers of natural science first utilized existing material sand then went on to create their own apps, simulations and digital supports for teaching biodiversity. The project aimed to promote critical thinking about the pedagogical facets and potential of apps.

3.1.7 Using Augmented and Virtual Reality for learning

Augmented and virtual reality have been proposed for learning purposes since the technologies were originally developed, and there is now a body of evaluated studies of how well they work as teaching tools.
Ibáñez and Delgado-Kloos [46] review the literature 2010–1017 on the use of augmented reality (AR) to support STEM learning specifically. They note that the majority of studies have measured the short-term retention of information by the students, typically by pre- and posttests. There is however a risk that the positive results are at least partly due to the novelty effect, longer-term studies are needed. Relatively few of the reviewed studies found problems with the use of AR systems, mainly due to the requirement to first train teachers and students in the use of the system itself.

da Silva et al [95] review the literature 2009–2017 on how to best evaluate augmented reality as an educational tool. They confirm that the majority of studies measured short-term retention of information. They also note that a large proportion of studies pose exploratory questions, indicating they are at an early stage of research. da Silva et al also make the point that few of the studies studied the use of AR in conjunction with other teaching tools, even though that could be assumed to be the normal state of day-to-day teaching. Most studies did not involve teachers either. This can be due to many AR tools requiring specialised skills in order to produce content, so that the teachers cannot create teaching materials on their own. The authors further note that studies would have benefited from studying their subjects with multiple methods in order to get richer data.

Finally, Parong and Mayer [64] compare the use of a virtual reality (VR) demonstration of how the human body works with a self-paced PowerPoint presentation containing the exact same information. While the students were enthusiastic about the VR presentation, tests suggest that those who had partaken of the 2D presentation had a deeper understanding of the subject matter. The authors suggest that this is due to the 2D PowerPoint presentation requiring less cognitive effort to process, and the self-determined pace letting the student assimilate information before moving on the next chunk of data, even as they use less time in total to go through the presentation. The animated 3D VR system adds distractions that take focus away from the important information in the scene. Parong and Mayer also compared a plain VR presentation with one in which the presentation was broken into shorter segments and the students had to write summaries of each segment before proceeding to the next. In this case the students had test results at a level similar to that achieved by the PowerPoint viewers, while still being enthusiastic about the technology.

3.1.8 Computational Thinking

Proponents of “computational thinking” argue that the skills an ideal programmer has—methodical problem-solving, ability to abstract, self-criticism, etc—should be inculcated in the general population [118].

In Italy there has since 2014 been a discussion on the introduction of computational thinking in compulsory schools (age 6–16) led by the Ministry of Education. In 2015, a general school reform was launched with the approval of the law n.107/2015. This law included computational thinking among key educational objectives. The 107 law introduced the Italian National Plan for Digital Schools which is a three years plan which is composed by 35 different actions for school digital innovation. In this plan there are different activities oriented to the introduction of computational thinking including a revision of related national indications. There is also a national project to introduce coding in primary school. This project includes 10 hours of coding in each primary school class. Till now, despite the fact that it is not compulsory for schools, the project has been very successful (e.g. Italy is the country scoring the highest number of participants in the European Code week [33] since its introduction).

The scientific committee for the revision of the national guidelines (Indicazioni Nazionali) has recently released a document proposing the inclusion of computational thinking in compulsory school curricula. When the Ministry of Education published the document, clarified that the revision will not imply the introduction of a new subject neither in primary school nor in lower secondary school. This will probably imply that computational thinking will be introduced as a transversal subject in primary school and within the existing subjects of Mathematics and Technology in lower secondary school.

This is a situation not uncommon in Europe – consider, for example, France, Finland, Sweden, and Norway have recently completed curricula reforms following this path [11].

Key Challenges

- The necessity of a good definition of computational thinking teachers can refer to (in order to identify objectives, assessment criteria, and possible synergies and differences with other subject matter).
- Accommodating new topics in the curriculum poses a number of difficulties, not least that it implies taking hours away from other activities.
- The introduction of CT in the curriculum calls for major in-service teacher training initiatives to up-scale competences.
- The necessity to involve school leaders so that they understand the importance of including CT and Programming and hence promote its implementation and support teachers' participation in in-service training initiatives.

The Institute of Educational Technology of the Italian National Research Council (ITD-CNR) has recently been involved by JRC (EU) in the publication of a Science for Policy report on Computational Thinking which provide a comprehensive overview and analysis of recent findings and grassroots and policy initiatives for developing CT as a competence for the 21st century among schoolchildren, and also to highlight the implications for policy and practice [28].

Bellettini et al [8] present a constructivist programme for introducing computational thinking that they have implemented and tested. It is based on a layered structure where the earlier layers introduce problem-solving skills without involving computers, introducing group work and project planning in higher layers, the final layer containing learning programming, facilitated by teachers with computer science training.

Heintz and Mannila [44] describe an effort they led to introduce computational thinking to all comprehensive school pupils, and their teachers, in the town of Linköping, by getting a large number of representative teachers to take part with the intention that they then spread the knowledge not only to their pupils. They note that the teachers were easy to get to introduce the concepts in their teaching during the campaign, but that this usually did not change the daily practice of the teachers. The teachers who took part reported that it was difficult to spread the ideas to their colleagues, due not only to lack of time, but also organisational issues, as they did not have a mandate to demand anything of their colleagues, but that school management, in case it even existed, often was not very interested in introducing new pedagogical ideas. Finally the teachers did not have a clear plan for how to add computational thinking into all relevant lessons, the suggestions made by the researchers were considered as too complicated. A final comment by Heintz and Mannila is that the use of tools such as Scratch [92] can fool teachers into thinking that they understand programming.

3.1.9 Girls Code It Better: a new policy for fighting gender stereotypes in Italy

According to recent studies conducted in Italy, negative gender stereotypes are among the causes that prevent female students from pursuing a career in the scientific and technological sector. Indeed, social conditioning and exposure to gender-biased teachers may have a detrimental effect on girls' performance in mathematics and also decrease their level of self-confidence in scientific subjects with long-term effects on their career paths. Therefore, new policies should be implemented, aiming at dismantling these misconceptions and boosting the female self-confidence in STEM.

On this regard, action has already been taken in Italy with “Girls code it better” (GCIB) [41], a project launched by Men At Work (MAW), an Italian employment agency, and currently involving 53 schools and 1413 middle-school female students. Supervised by a school teacher and an expert in the field of STEM (the coach-maker), during the course of the academic year these girls attend extra-curricular courses of coding, informatics and technology with the scope to become more familiar with the scientific subjects and develop their own technologically-advanced “product”. The aim of this event was twofold: on the one hand, the organizing institutions hoped to make school teachers and students’ parents more aware of the dramatic consequences of gender stereotypes through the presentation of the related research projects carried out by scholars of the involved universities. Secondly, the event was born with the intent to provide the girls of GCIB with new role models in the field of STEM, as well as to give them the opportunity to exhibit the works which they developed throughout the year.

Therefore, the entire day was full of activities directly involving the participating schools. Upon their arrival in Milan, the girls attended a conference where two female professionals working in Microsoft and some female students of Bachelor in Management and Computer Science (BEMACS) at Bocconi University told their experience in the field of STEM. What does it mean studying STEM? What are the main challenges for female professionals in this sector? How can women improve the society by working in STEM? These are only a few questions that the guests answered through direct examples and inspiring videos. Afterwards, an exhibition took place in the hall of Bocconi University. New benches for the school garden, cleaning robots, anti-theft magnets for clothes, a temperature and humidity recorder (the Season Box) and a voice controller are some inventions displayed by the girls participating at GCIB. These products are the result of a creative process starting with a brainstorming session and followed with coding and electronic classes. Firstly, divided into teams and under the directions of the coach-maker, the girls should answer to the question: What can we do to improve our school? Several projects aiming at protecting the environment and improving the school’s facilities usually come to their mind, but the students should be able to select only the feasible ones which can turn their ideas into a tangible product. In this phase, the coach-maker is the key player: It is crucial to understand the abilities and interests of the girls and to organize the courses in a way that meets the students’ needs. For this reason, the students are assigned to different teams involved in a specific phase of the production process: some girls attend classes of coding and informatics, while others learn the basics of web designing and 3D printing. In the end, thanks to the coordination of these groups, the final work is delivered and ready for ensuring more comfortable and environmentally-friendly classrooms.

3.1.10 The case for ICT-supported teaching

A fundamental point that has to be addressed is whether ICT tools bring anything but novelty to the classroom. A study which argues their utility was made by Ballantyne et al [5], where a computer-generated presentation of climate change was shown to high school students. The various statistics presented as bar charts on the surface of the Earth were perceived as enlightening by the students, even if they, for several reasons, failed to see their own role in climate change and its mitigation. The authors suggest that making the presentation more interactive would let the students explore the data more deeply, and thus perhaps gain an even better understanding of the issues.

While our work is aimed at secondary school, there is interesting work on using digital storytelling in preschool as a pedagogical method. Bertolini [10], working within the Erasmus+ Stories project, suggests that this is a suitable way to introduce media literacy at an early age. Storytelling is a deeply human activity and a way to make sense of the world. It is thus a suitable activity to explore the world in a preschool setting. Using digital tools to record and enhance the stories told by the children is a natural next step.

3.1.11 Teachers' efforts to develop their teaching practice with digital technology

The decision to strengthen digital competence by the government, provides additional support for science teachers to work with, e.g., simulations in science. Several initiatives have been taken in Sweden with the aim of promoting digitalisation. Below we will present five different case studies.

In the thesis by Willemark [58] teachers' efforts to develop their teaching practice with digital technology in the authentic environment over time was explored. The study included data from a three-year school development action research project, in a Nordic elementary school context (Sweden, Norway and Denmark). The project aimed to answer the research questions: "of how teachers' efforts to develop their teaching practice with digital technology can be identified, understood and supported." To answer the question two theoretical frameworks was used: activity theory [72] with expansive learning and TPACK (Technological, Pedagogical and Content Knowledge) [112]. As a result Willermark presents seven aspects to take into account "when designing professional development initiatives: 1) to conduct initiatives where the individual teacher's knowledge and condition is taken into account; 2) to pursue initiatives in an authentic setting, in teaching practice; 3) to pursue practice-focused initiatives, where innovations can be spread; 4) to place the technological, pedagogical and content aspects in the foreground; 5) to conduct initiatives where technology is considered as a means rather than an end; 6) to balance challenges and boundaries with proper resources and support; and 7) to have a long-term perspective on initiatives, as it is time-consuming to develop teaching practice and since it constantly needs to be renewed as a result of continuous technological development."

Öman and Sofkova Hashemi [73] have studied how traditional teaching practices need to be challenged and adapted to the use of multimodal ICT tools. Their case study describes how, even though the pupils were supposed to produce video material describing one of the planets in the solar system, the teacher's presentation of the material focussed on the verbal and written aspects of the process and a walk-through of the features of the video editing software taking precedence over discussing the actual output that was to be produced by the pupils. The suggestion is that teaching has to take the multimodal nature of ICT tools into account and not get so caught up in the details of the software that the intended pedagogical content of the lesson is obscured.

3.1.12 Support learning and teaching of chemistry

With the overall aim to understand how we better support teaching and learning of under-------graduate chemistry students Manneh [31] presents a model "progression in action" to engage students in for them meaningful activities. Manneh emphasizes difficulties for the students to understand chemistry and mentions, among other things, the large number of abstract concepts and models that they are expected to use.

3.1.13 Mathematics teachers' motives in discarding digital technology

While earlier research shows that despite digital tools being promoted in the education policy, mathematics teachers use these tools less frequently as compared to teachers in other subject areas [5, 22]. As part of a broader study, set out to understand how and why mathematics teachers use technology in their classroom practice, Bretscher [6] surveyed English secondary school teachers' technology use. The study involved 188 teachers in 50 different schools and identified a gap between policy expectations and the actual use in the classroom setting. With the knowledge of an existing gap Utterberg and Lundin [110] explore the reasons for discarding digital tools and with a focus on mathematics education. Ten teachers, who themselves expressed that they discarded digital tools in their teaching, have been interviewed. Three conditions were identified as important for teachers' activities: policy, teacher practices, and digital tools.

3.2 Case studies in Ireland

3.2.1 Background and Context

The case studies have been performed at Coláiste Mhuire Co-Ed (CMCE), a secondary school in Thurles Co. Tipperary.

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The following equipment is in use in CMCE:

Equipment/room	Number of Computers	Operating System	Interactive projector
Room 7	29	Windows	No (is projector but not interactive)
Room 11	25	Windows	No (is projector but not interactive)
Room 12	21	Windows	yes
Room 32 (Extn Lab)	25	Windows	yes
Room 15	16	Windows	yes
Study Hub 1	5	Windows	no
Study Hub 2	5	Windows	no
Chromebooks in Trolley (portable)	10	Chrome OS	N/A
iPads	10	Apple	N/A
Micro Bits	20	Microsoft	N/A
Classroom (28)	Computer in each room, Apple TV in each room Some rooms also have visualizers.		In all rooms, some are interactive

3.2.1.1 Training teachers get on using ICT tools

CPD has been provided both by outside sources and teachers within the school to teach various apps for the iPad and in Google apps for education.

- In September 2012 Camara [13] delivered in-service on using Google to all staff.
- Staff have led CPD sessions in google drive, google sites, google classroom, google forms, Prezi [82], Kahoot [53], popplet [80], padlet [74] and Twitter.
- Wriggle have provided department specialised ICT training using iPads to Whole School, Geography, English, Art, Science, Irish, History, Physical Education
- 2 staff completed Microsoft Digital leader training with the ETB in the hope of further dissemination
- 2 staff involved in TL21 eportfolio project which led to an ATS2020 project—they have helped with in-service on using e-portfolios
- App of the month idea—display of one app and an accompanying website of training (staff can do 1 hour of personal croke park hours [4] for using it in the month)
- Staff training on twitter and we are currently piloting use of twitter as part of the Cosán process [16]

- IT was a focus of peer observation last year
- 2 groups were involved in the Digital Championship Scheme last year and 1 further group this year

3.2.1.2 How is ICT use perceived by the students?

As part of our Digital Strategy, to prepare our current Digital plan we surveyed students and their parents and also conducted a focus group with students.

The overwhelming report from the focus group was that students viewed ICT use very positively and considered that the use of ICT was productive and supportive. They were especially commending of the use of Google classroom.

The school was a pilot for the Erasmus project Selfie [93]. Students were required to reflect on ICT usage for this project. The overriding consensus from the report is that students viewed our use of digital technology more favorably than either management or teachers did. Is also interesting to note that in most of the answers we were coming out in the margins of 3. given that 2.5 is the middle we were better than 2.5 and rarely achieved over 4 in any of the criteria. This suggests lots of room for improvement.

3.2.1.3 Teachers' difficulties with using ICT Tools

Staff report the following difficulties:

- Time to learn and prepare
- Don't know enough about it – lack of training
- Not convinced that it improves the learning of students
- Wifi in certain areas of the school
- Lack of 1/1 devices of students
- Students lack of wifi at home

3.2.1.4 What are the students' difficulties with using ICT tools?

Students report the following difficulties:

- Not being allowed to use the technology in summative exams
- Some teachers not using ICT
- No wifi at home

3.2.2 Kahoot

3.2.2.1 Specific courses/subjects

I had finished a module of work with my third year science students and I wanted to gather some formative data. I wanted to do this in a non-formal setting, so I opted to use KAHOOT! for the purposes of instant feedback on how my students were learning. KAHOOT! is, according to their own website, a "game-based learning platform, free for teachers of awesome and classroom superheros" [53]. What is not to love? I felt that this game would be a great suit for my students as they had just finished text heavy content (Evolution and Human Health) and this Kahoot! would provide a light hearted relief helping to make an otherwise academic task into something more informal and fun. The percentage of students with iPads in my class is approximately 50%. I had to be sensitive to the students who prefer working on their own and not just automatically pair students in groups against their will. I eventually gave the students with iPads a choice of

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whether they would prefer to work on their own or whether they were happy to go in groups of two. All except one student were happy to pair up. I felt that I did not want more than two to a group in case a student might seize an opportunity to let their peers do the work. That left me with one student who had no group and no iPad. I allowed that student to work individually and I gave him my iPad to use, which he was quite happy about.

The software is so easy to use. The website has everything needed for a successful quiz. All that was required was to log on to create.kahoot.it and look up relevant topics to quiz the students on.

Then, I could find different lengths of quizzes to use depending on the amount of time I had left in my lesson or I could tailor the time to suit the kahoot! as a starter to a class or if I wanted it to be a revision tool (as I did during the initial use). The students were given a code to put in and they then had access to the question. I could monitor who was participating because they then had to put in a group nickname (after having been given the warning that anything inappropriate would be taken down immediately!). The students immediately responded to the competitiveness of the quiz as they were able to see what group was leading at any particular time. Each round is played against the clock so it adds a further layer of competition as, not only are they playing against the other teams, they are also playing against themselves. They also earn more points based on how quickly they answer the questions.

3.2.2.2 Evaluation

I believe that this method of assessing my students is highly effective. It has long been established that children learn best through play and that they love to play computer games. I found that after using the bank of questions available on the Kahoot! webpage, some of the questions were repeated within the same quizlet. After a while, I found it hugely beneficial to create my own KAHOOT! quizzes which were tailor made to accommodate differentiation and to target key learning intentions which I had for my class. This was just to assist the teaching and learning but the students were unaware of any of these precursors to the quiz development.

The quiz had an extremely positive effect on the student. They loved the visual impact of the game and the instant feedback which they received. They loved the freedom to choose their nickname at the start of the quiz.

After several more sessions of KAHOOT! to formatively assess other topics in the science class, I realised that I could use this tool in a flipped classroom format. Instead of me developing the quizzes, I gave each group a task of developing their own KAHOOT! and over the next few sessions, each group was given a scientific topic which they had to develop a quiz and share it with their peers. This allowed peer assessment to take place, again in a very informal, secure surrounding. The students developed a deeper understanding of the topics by writing their own questions and had a lot of fun claiming ownership of the result.

Of course, the downside to this is the availability of iPads. In my school it is not too much of an issue as there is a good uptake in the use of iPads in the school and also we have a class set of iPads which we can use. However, it is dependent on this availability for it to be used with any meaning in a school. Saying that, it is an excellent Assessment for Learning tool and it is available as a tool for all subjects and all year groups.

I found the community atmosphere of the game, the bonding between the teams and the option for discussion around various themes and topics to be phenomenally beneficial and can be differentiated or extended to both ends of the learning abilities.

3.2.3 Mentimeter

3.2.3.1 Specific courses/subjects

In my science lessons, during or at the end of a topic, for example, The Circulatory System, I like to recap on what students have learned and identify areas for further development by using Mentimeter. Using this tool I can create templates and for each template a specific code is generated. Students log onto http://www.menti.com/, enter the code and are directly taken to the template I have created. Mentimeter has a variety of template types to choose from but my preferred methods for this type of assessment means are Word Cloud, Q & A, Multiple Choice and Open Ended.

Word Cloud allows for quick-fire key word production from the students and I can limit the amount of answers received from any one student to prevent stronger students solely generating answers. Q & A allows students to ask questions anonymously, by allowing them to enter their questions on their phones/tablets and they appear on the board for the rest of the class and the teacher to answer.

Multiple Choice allows the teacher to create online quizzes and I can choose to allow students to progress at their own pace or it can be teacher led. In this template I can choose if students can see the correct answer, make more than one attempt at a question and if they get a percentage score, which I think is really useful for summative assessment.

Open-Ended allows students to input answers to an open-ended question displayed on the board. Answers can be displayed in speech bubbles, one by one or in a grid. One by one I find works well. At the end of a topic I can display an open-ended question such as ‘What areas am I still unsure of this topic?’, as students enter their remarks I can deal with them one by one and use it as a method of further study or recap and then move to the next problem area.

3.2.3.2 Evaluation

I found the use of Mentimeter successful in my classes from an assessment point of view and in terms of student engagement. There does however need to be some level of regulation and classroom management especially when using Word Cloud and Q & A as words and questions appear anonymously from the students on the board. There is a feature that allows profanities to be excluded for your given language and emojis which is certainly helpful.

Students really enjoy the visual creation of an online Word Cloud and I find the app not only caters for different learner styles but also for the modern student by engaging them interactively online in the learning process. For those who work better by writing I sometimes ask students to create their own mind map in their copies using the words generated on the board, in this way differentiating for all.

The Multiple Choice template can be completed individually or in pairs and creates a fun, competitive environment. Making your own templates, depending on the type you choose, may take some preparatory time but for the use in Science lessons and as formative and/or summative assessment, once they are created they can be reused over and over again so it is a valuable tool to have. In the future I would like to look at passing my responsibility to the students and asking them to generate their own quizzes that they could then use to peer assess and give more autonomy in the class. An obstacle I may meet in this task is limited availability of iPads in class as not all students are using iPads in school. One way of getting around this would be to allow students to create and implement their quizzes in class rather than for homework as

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in most classes there is one iPad between two, this would just slow the process somewhat but nonetheless encourage peer cooperation.

3.2.4 Educreations

3.2.4.1 Specific courses/subjects

I was teaching volumetric analysis of acids and bases when I decided to try Educreations [27]. This topic has a large emphasis on calculations. Some students were able to understand the calculations very quickly but a few found them difficult and they struggled to complete them at home, even though they had a worked example in their copies as a reference.

Educreations allows teachers to create and share lessons, search through an archive of lessons from other teachers and even create a flipped classroom by designing lessons that the students can access at home. Educreations has a number of options when you log on, either through their app or online. I went with the basic package which is free, this option still allows you to record and share lessons using basic whiteboard tools. The app could be used on either a tablet or desktop computer.

The advantages of creating these lessons is that they can be prepared in advance and saved for future reference. Or in my case I used them for a flipped classroom. I accessed the question I wanted to answer online and I took a screenshot of the question on my iPad. I was then able to upload this image to my recording. Using the whiteboard tools I was able to circle the important information for answering the question while recording myself talking through and explaining the question. I then used my stylus to answer the question, recording continuing throughout, while I continued to explain how I was answering the question. Once I watched back the recording and I was happy with it, I uploaded it to my students' Google classroom. The students now had remote access to this worked out solution and they could go through it at their own pace when attempting to answer similar questions.

3.2.4.2 Evaluation

I felt the results of using Educreations and the flipped classroom were very successful. The students found it really helpful being able to access the recording at home. Their confidence when attempting to answer these questions improved, in particular the students who were struggling to answer the questions at the beginning. Some attempted more of the question than they would have before, when they would not have attempted the question at all—instead feeling like they couldn't do it. By using Educreations, the student's critical engagement in attaining challenging learning outcomes is possible.

The benefit to the students is that it allows for differentiation across the class as students work at their own pace. It allows them to view the recordings, take notes and manage their learning from home if required. Students can reflect on the recordings and take ownership of their own work. Students can also negotiate their learning thereby increasing their autonomy and effectiveness as learners.
This lesson is easily replicated as lessons can be saved and used for future reference.

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3.2.5 Quizlet

3.2.5.1 Specific courses/subjects

Quizlet [60] was used as part of a Home Economics nutrition class on nutrients. Students used their own digital devices whether that be an iPad or a phone. The app, quizlet was used on the most part by students. Students were prepared for the activity by firstly taking part in group work on the areas of protein, carbohydrates and lipids. They were given input by the teacher. Afterwards, they were asked to make their own quizlet on one of the nutrients studied. They then matched each of the questions to answers and tested themselves on their own activity until they were confident on that nutrient. Teacher had a quizlet prepared for the learners which they then completed competing with each other in a matching activity. It was a great motivator for the learners as I could see that they continued to work on the activity at home. In the following lesson, learners completed a group work placemat activity and a question and answer session using google forms. Students had a much greater understanding of the area of nutrition. Students worked on definitions on the most part and have used it since this activity on food commodities and have made their own quizlets at home through homework and have shared these with each other in order to include the competitive aspect to the app.

3.2.5.2 Evaluation

This was very effective for student learning and motivation in the classroom. I know this as students continued to take part in the activities at home. They wanted to make use of it and they found it very effective for areas like nutrition which were difficult to learn. The competitive aspect of it helped motivated students and test scores through the use of google forms show how effective the tool was as results were much better in comparison to tests completed previous to this. Student results increased between 10 and 30%. This strategy could be applied within any subject area which has some wordy nature to it whether this be English or science, especially when there is a need for definitions. I, however, would not use the testing area as it asks students to write out the exact definition I had given and if they miss a word or if the misspell any word, they are given a score of zero. Therefore, I think it can be used more effectively through an activity of matching.

There may be an issue in some schools regarding iPads and having use of digital devices. I think this could easily be worked with through the app or even through the internet on their phones. I allowed them access to their phones in class so they could take part. It could also be worked with in groups but I think they gained more when they worked on it alone. It gives them the right answers in a definition section so if they know they are getting a lot wrong themselves they can check it out.

The app is very beneficial to students for assessment and for learning definitions, in particular. I think it could be used in most subject areas and in most schools as most subjects have an aspect of literacy. I think it may be more useful with older learners or more mature learners as they will have the confidence to constantly look back on the definitions that are on the section in order to learn more.

3.2.6 Google Classroom

3.2.6.1 Specific courses/subjects

I have just finished the topic “The Respiratory System” with my Sport and Recreation Studies group. As all the class group have internet access and google accounts I decided to explore this module using Google Classroom. As a medium Google Classroom allows for effective communication, sharing of resources as well

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as assignment submission and feedback. Google classroom is an excellent storage site and is easily accessible for all students. I found it to be extremely useful for its announcements portal with regard to preparatory activities.

As it is linked to all participants' email addresses everyone receives a notification email when an announcement is made. For instance when conducting an experiment during this module, students needed to bring materials and recording devices with them to class. Before this class I was able to link them on a video demonstration of the experiment as well as provide them with a gentle reminder to bring relevant materials to class. During class time, I was able to display the announcement coupled with the video using the overhead projector. This set the scene for much collaboration and questioning throughout the lesson.

I felt that Google classroom allows for a continual, professional relationship outside of timetabled class periods. I was also able to provide the students with a clear method on the Google Classroom stream. As a follow up activity participants needed to submit a 500 word reflection. Google classroom facilitates this very well with an Assignment Submission section. Candidates found that the assignment was far more straightforward as there was a constant record on the stream to refer back to. This certainly made this assignment experience far more enjoyable and easier for both the tutor and the students.

3.2.6.2 Evaluation

I found Google Classroom to be quite effective as both a teaching resource and as a storage site. From a teaching perspective it allowed me continually link in with students outside of class time. I found that this really added to the quality of each lesson. For instance, I was able to make frequent announcements in the class group "stream", providing updates on assignment submission as well as upcoming class topics/content.

Google classroom has allowed my lessons to be quite interactive. Students can engage in much discussion in the comments section below any posts that the tutor makes. I felt this really impacted the students' learning and promoted rich questioning amongst the cohort. I found that students who were not as vocal in the classroom thrived in the discussion section of Google Classroom. As I am teaching in a Deis school [22] I feel that Google Classroom certainly delivers equality of opportunity to student learning.

Teaching methodologies such as co-operative learning and peer assessment were facilitated excellently by Google Classroom. Students were able to pair up with iPads and discuss the posts that I had posted on the Class stream.

Overall I felt that students took more ownership of their learning as a result of Google Classroom. The comments and discussion sections really allowed participants to further examine topics through questioning and collaboration. I will definitely look to use this resource with my other class groups.

3.3 Case studies in Italy

3.3.1 A torrent in a gutter—moving sediments

3.3.1.1 Context

The classes affected by the initiative are the first two years classes of secondary school (specifically a Technical Institute).

The activity carried out mainly involves the disciplines: Earth Sciences

3.3.1.2 Materials and resources used and available in the school

In the Institute, each class is equipped with a touch screen connected to the Internet, teachers and students have personal access to the Google Apps for Education suite [39].

At the beginning of each school year, the Digital Animator organizes an in-depth course on the use of educational technologies.

3.3.1.3 Subjects involved

The activity carried out mainly involves the disciplines Earth Sciences and Physics

3.3.1.4 Activity

The laboratory activity was set on the basis of the PEC cycle (Forecasting - Execution - Comparison); the pupils, after an initial phase of motivation, were given an incoming test (IN test), then it was decided to identify the objectives of the experimental activity and to design the same in such a way as to be able to obtain the desired information (discussion in work groups and comparison among them).

The teacher proposed to shoot the simulation of the stream with a video camera and to use the Tracker program to follow the movement of the particles of gravel carried by the current, also highlighting the speeds in the various parts of the course. It was therefore decided to let the students exercise first with the software chosen so as to make them able to apply it to the study of sediment transport.

After this preparatory phase, each group carried out the experiment, according to the agreed modalities, the filming was carried out and, at the end, the videos were processed in the Informatics classroom with Tracker in order to obtain the greatest amount of information from the experimental study.

The whole class participated in a final discussion to draw conclusions from the results obtained and to evaluate, by analogy, the effects of current in real watercourses.

3.3.1.5 Evaluation

The evaluation of the learning process was carried out based on the following indicators:

- in/out test analysis;
- direct observation of the students while they were operating;
- motivation;
- ability to establish relationships and/or draw conclusions between the experimental observations, and the theoretical elements analyzed during natural sciences lessons and processes/phenomena;
- quality of the schemes and/or reports produced (both on paper and in electronic form);
- tests carried out to verify the understanding of the concepts, the acquisition of the contents and the ability to speak up using a correct scientific language;
- personal contribution in class discussions.

The students showed an interest in the educational activity, the results of the OUT test showed a good understanding of the main concepts faced and, in general, a greater terminological property combined with a more solid awareness of the problems connected with the phenomena studied, compared to what emerged in the entry test.

The educational use of technologies had been a significant motivating factor, which encourages us to follow this path, which combines hardware and software tools with the experimental investigation carried out with traditional techniques.

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3.3.2 La Spezia schools located in areas at risk from water: study of the catchment area of the Canale Dorgia

3.3.2.1 Context

The calamitous events that affected Liguria, and the numerous Alert states, led the mayors of the La Spezia area to issue ordinances to suspend educational activities. As a result, pupils have asked questions aimed at understanding, on the one hand the underlying causes of flooding phenomena, and on the other, the criteria with which some schools were closed, and others were not involved by these provisions.

The classes affected by the initiative are the II and III classes of the lower secondary school of ISA 6 in La Spezia.

The activity is aimed at making students understand:

- the meaning of the water catchment area of a watercourse and the methodologies to define its cartographic limits and the areal extension;
- the main aspects of river dynamics;
- the meaning of hydraulic risk;
- the correct behaviors to be taken in case of risk and/or disaster;
- the municipal civil protection plan.

3.3.2.2 Materials and resources used and available in the school

- LIM
- C.T.R. taken from the site http://geoportale.regione.liguria.it/geoviewer/pages/apps/repertorio
- Thematic cartographies attached to the municipal territorial planning instrument (PUC - Municipal town planning), downloadable from the website: www.comune.sp.it;
- Satellite images downloadable from Google Earth;
- word tools.

The activity was positively perceived as each phase of the activity was developed starting from moments of confrontation and reflection on problematic situations with the aim of involving students in the objectives of the work and stimulating/guiding them to formulate and verify operational hypotheses.

This approach, a wholly new one, was based on the concrete experience, in which the teacher is an active promoter of the growth of students' pleasure of "discovery", understood as "novelty of knowledge", through the recognition of determining role of concrete experience in structured and unstructured situations (laboratory, in the field, in the classroom, and in the environment).

3.3.2.3 Subjects involved

Biology: relationships between soils - porosity - permeability - granulometry - presence of water in the soil - flora and fauna.

Economic geography: relationships among soils - porosity - permeability - granulometry - economic activity.

Ecology: pollution of groundwater by chemical fertilizers and industrial and domestic wastewater.

History: exploitation of water resources in ancient civilizations and consequent socio-economic consequences.

Earth sciences: waters in the subsoil: wells and springs, hydrogeological instability.

Chemistry: characteristics and chemical composition of the soil

Mathematics: percentage calculations, equivalences.
Citizenship and Constitution: basic concepts of sustainable development for a correct use of water resources of the subsoil and the territory (reduction of hydrogeological risk).

3.3.2.4 Activity

Phase 1. ACTIVITY INTRODUCTION
The teacher, making reference to the class discussions, of November 2014 following the calamitous events in areas adjacent to the La Spezia territory, let the students reflect with the help of questions, visualization of images and/or reading newspaper articles and the original document which the mayor of the municipality of La Spezia suspended educational activities in some schools in the areas at risk.

Phase 2. DEFINITION OF THE HYDROGRAPHIC BASIN.
The phase is divided into two parts:
Identification of the basin's limits and the location of school buildings;
Group work to analyze the various thematic maps

Step 3. SEARCH FOR HISTORICAL IMAGES.
In this part of the educational segment, the students carry out a research of historical images to define the original river's bed course and the progressive urbanization that led to the reduction of water absorption surfaces.

Phase 4. EDUCATIONAL OUTDOOR ACTIVITY
The educational output is aimed at observing and documenting:

- anthropic interventions along the river (bank walls, bridles, ...);
- shore and/or bottom erosion phenomena;
- water course status (accumulation of plant materials, waste, bulky or inert materials, ...)
- sampling of rocks and soil.

Phase 6. SUMMARY AND REPORT OF THE ACTIVITIES CARRIED OUT

- The various groups produce paper documents and/or posters and/or presentations in PowerPoint to describe the activities carried out.
- Class discussion of the work carried on.

3.3.2.5 Evaluation

The evaluation of the learning process was carried out based on the following indicators:

- in/out test analysis;
- direct observation of the students while they were operating;
- motivation;
- ability to establish relationships and/or draw conclusions between the experimental observations, and the theoretical elements analyzed during natural sciences lessons and processes/phenomena;
- quality of the schemes and/or reports produced (both on paper and in electronic form);

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- tests carried out to verify the understanding of the concepts, the acquisition of the contents and the ability to speak up using a correct scientific language;
- personal contribution in class discussions.

Cooperative work group has allowed a supportive learning among peers in terms of knowledge/skills. Moreover, the class discussion of the works made allowed to critically analyze the strengths and the limits and/or errors of each individual product; thus providing useful elements to the students for a self-assessment of the learning processes.
This experience has strengthened the belief that the student is the real protagonist of the teaching-learning system and must be stimulated in this process through interventions aimed at letting him participate in its educational training by establishing moments of discussion with the purpose of understanding the skills owned on a whatsoever topic.

3.3.3 Earthquakes: natural phenomena of a planet continuously searching balance

The proposed activity is aimed at allowing students to acquire a working methodology for a correct approach to the study of scientific disciplines and, specifically, to issues related to earth sciences. The teaching activity is structured in shared educational moments, in which each individual student is an active protagonist of his own learning, in relation with his own potential and specific personal aptitudes. This implies the overcoming of the notional and quantitative approach, favoring laboratory teaching. The teacher is an active promoter of growth, in the students, of the pleasure of “discovery”, understood as “novelty, of knowledge”, through the recognition of the decisive role of concrete experience in structured and unstructured situations (laboratory, in the classroom, and in the environment). The operational freedom left to the students in the various phases of the journey, contemplating the possibility that they might make mistakes, with the aim of letting them reflect on the work in search of corrective strategies, fosters a significant learning.
The activity is aimed at pupils of grade III secondary school, and was tested in different school contexts in the PON Scientific Education 2011–12 regions - II year (http://www.scuolavalore.indire.it/nuove_risorse/terremoti-fenomeni-naturali- di-un-pianeta-alla-continua-ricerca-dellequilibrio/).

3.3.3.1 Materials and resources used and available in the school

The path includes the use of resources and online simulations.
The school is equipped with a laboratory with hardware and software necessary for access to internet resources.

3.3.3.2 Subjects involved

The activity carried out mainly involves the disciplines Earth Sciences.

3.3.3.3 Activity

The proposed training activity is structured in seven didactic segments, each of which presents elements for a flexible treatment, in order to respond to the pragmatic needs of each individual teacher and numerous ideas for interdisciplinary developments/in-depth studies.
The work plan begins with an introductory activity, developed in a problematic key, aimed at:

- stimulating the interest of the students;

- bringing out the knowledge in their possession;
- starting a path aimed at correcting misconceptions through the acquisition of scientifically correct and rigorous concepts.

The teacher, in this phase, plays a strategic role on which the success of the educational proposal and the achievement of the set objectives depends.

The proposal continues by entering into the specifics of the phenomenon by examining: origin, dynamics and effects of earthquakes. Significant spaces are dedicated both to practical experience (with the use of poor materials and with references to real situations) to be built together with the students, and to research data, simulations, videos, photos, etc. through websites, with the aim of making acquire their awareness of the relationships between plate dynamics - seismic phenomena - volcanic activity. Finally, a discussion of the issues addressed to the prevention and reduction of seismic risk is proposed, with the objective both to develop correct attitudes in the event of an earthquake, and to build a culture based on sustainable development through correct territorial planning.

3.3.3.4 Evaluation

For the assessment of knowledge, skills and competences of the children, the following are proposed: following criteria:

- direct observation of the laboratories motivation;
- pupils while they are operating during activities experimental, theoretical topics and natural processes/phenomena
- quality of the schemes and/or reports produced (both on paper and in electronic form);
- test results (oral and written) to verify the understanding of the concepts, the acquisition of the contents and the ability to exhibit using a correct scientific language personal contribution in class discussions.

From the analysis of the tests in/out the teaching activity, strengths of the present proposal are to resort to:

- problem solving with the aim of improving learning and the ability to extend concepts to real
- situations and/or problems;
- schemes, maps, images, thematic maps, videos;
- group work, aimed to:
    - improve student relationships,
    - strengthen the sense of belonging;
    - stimulate discussion and peer collaboration to facilitate learning and self-esteem
    - empower students, giving them specific tasks.

3.3.4 Energy: a vision at a glance

3.3.4.1 Context

The classes affected by the initiative are the first- or second-year classes of secondary school (specifically a Technical Institute)

The activity carried out mainly involves the disciplines: Physics and Mathematics

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3.3.4.2 Materials and resources used and available in the school

In the Institute, each class is equipped with a touch screen connected to the Internet, teachers and students have personal access to the Google Apps for Education suite. At the beginning of each school year, the Digital Animator (a designated teacher at the school [68]) organizes an in-depth course on the use of educational technologies.

3.3.4.3 Subjects involved

The activity carried out mainly involves the disciplines Physics and Mathematics.

3.3.4.4 Activity

The laboratory activity, included in the programming of the Physics course, was set based on the PEC cycle (Forecasting - Execution - Comparison); after an initial phase of motivational type (discussion centered on the energetic problem), an input test was given to the students (IN test). In the next lesson, starting from some of the answers given to the IN test (those relating to heating), internal energy was identified as a reference indicator for recognizing other types of energy. The attention was then shifted to a type of energy easily identifiable by the students: the kinetic energy. In this phase the dialogue with the students and the guided discussion prevailed through which the students were led to reflect on what happens at the energetic level during the fall of a body in order to lay the foundations of the concept of potential energy and the principle of energy conservation. An experiment on the fall of an object, taken with the camera and analyzed with “Tracker” [107] has made possible to reach a quantification of the kinetic energy and of the potential gravitational energy and a first confirmation of the conservation principle.

With a similar approach, the relationship between the compression degree of a spring and the speed of a trolley launched by the spring itself was experimentally studied, with the aim of consolidating the conservation principle and identifying a second type of potential energy, the elastic one.

The phases of guided discussion and the analysis of the experiments made it possible to take stock of the situation and to prepare a summary sheet on energy, “what they say about it” (conservation, transformation, types and forms of energy, units of measure, expressions of some forms of energy).

Starting from the conservation principle, the students were noted as an apparent contradiction was inside the phrase “energy consumption”, which seems to be associated with the loss of energy and not with its conservation. This provocation has the aim of starting a reflection on the “quality” of energy and the possibility of using it to make changes.

3.3.4.5 Evaluation

The activity carried out either in the classroom, or in the laboratory, was welcomed by the students; the pupils showed interest both in the subjects they developed and in the method; for a group of students, however, interest and participation have progressively diminished, almost certainly due to a difficulty in following the development of the activity and then understanding the concepts gradually analyzed.

The use of the Tracker program, which made possible to obtain significant data from the analysis of the video footage of the object used (an orange) was nevertheless received with particular interest by all the students, who perceived the potential offered by information technology in experimental data processing. In general, the use of sensors, video recordings and appropriate programs dedicated to the numerical and graphic processing of the collected data constitutes an important evolution in the didactic study of physical, chemical and biological phenomena, provided that the revision of the traditional approach is taken into consideration of laboratory activities. However, all this cannot be separated from a serious updating of the teachers, both on the knowledge of the technologies and, from a didactic point of view, on the methodologies that can be followed with the use of the same.

3.3.5 Conservation of mechanical energy in a harmonic oscillator

3.3.5.1 Context

The activity involved students of class III section A of the ISA 6 - “Ubaldo Mazzini” Middle School of La Spezia, in a didactic workshop organized in two stages: the first aimed at verifying the relationships that exist between elongation of the spring and applied load (Hooke's law), essential for a strengthening of the concepts of force, weight force, elastic force, reference system, the second, in which we proceed to verify the conservation of mechanical energy (potential energy elastic and kinetic energy) in a harmonic oscillator. The school, located in the city center, is attended by students mainly of Italian nationality with the presence (10%) of foreign students, mainly: Chinese, Dominicans, Albanians and Romanians willing to study and show their good skills in the scientific subjects.
Experience has involved the fields of physics and chemistry.

3.3.5.2 Materials and resources used and available in the school

The school is not equipped with scientific laboratories. Most of the experiences are carried on in the classroom with the help of poor materials. The laboratory activities that require specific equipment are carried out at the ISS Capellini Sauro (High School) based on a specific project of continuity and orientation.
The use of ICT is positively perceived by students, especially with regard to data collection and measurements. I have not noticed any difficulties in the use of this latter from the students, while some resistances and perplexities emerge from the colleagues especially those of the humanistic areas.

3.3.5.3 Subjects involved

The activity carried out mainly involves the disciplines: Physics and Chemistry

3.3.5.4 Activity

ACTIVITY INTRODUCTION
In this phase was illustrated to the class the educational training by briefly indicating its objectives, practical aims and work methodology in order to let them participate in the activity. In particular, I focused on the meaning and role of the test in/out informing them that the experiment had the task of:

- ascertain the initial competences regarding energy (test in) and verify if these had been modified and/or deepened during the course of the didactic action (test out);
- evaluate the effectiveness of the educational training and identify the strengths and weaknesses;
- study strategies aimed at correcting and/or improving the criticalities detected;
- represent a self-assessment tool.
- Give the IN test
- Discuss the IN test and plan the experiments
- Carry out the experiments
- Discuss the experiments
- Results of the OUT test

3.3.5.5 Evaluation

The evaluation of the learning process was carried out based on the following indicators:

- in/out test analysis;
- direct observation of the students while they were operating;
- motivation;
- ability to establish relationships and/or draw conclusions between the experimental observations, and the theoretical elements analyzed during natural sciences lessons and processes/phenomena;
- quality of the schemes and/or reports produced (both on paper and in electronic form);
- tests carried out to verify the understanding of the concepts, the acquisition of the contents and the ability to speak up using a correct scientific language;
- personal contribution in class discussions.

Cooperative work group has allowed a supportive learning among peers in terms of knowledge/skills. Moreover, the class discussion of the works made allowed to critically analyze the strengths and the limits and/or errors of each individual product; thus providing useful elements to the students for a self-assessment of the learning processes.

This experience has strengthened the belief that the student is the real protagonist of the teaching-learning system and must be stimulated in this process through interventions aimed at letting him participate in its educational training by establishing moments of discussion with the purpose of understanding the skills owned on whatever topic.

3.4 Case studies in Sweden

3.4.1 Background and context

The Ronna school is a grade 0–9 school in Södertälje, south of Stockholm. Ronna School is a primary / secondary school with about 750 students in a city 30 km south of Stockholm. The school is a multicultural school with the language as the key to knowledge acquisition . To enhance the quality of teaching, the school strives to have two teachers in each classroom and emphasize on language and educational development practices.

The school is well equipped in technology and all classrooms have projectors. All students in year 6–9 have Chrome book that they can take home and use on weekends and in the summer. The students in year 4–6 do not have Chrome books. They can borrow tablets during the lessons. All teachers have Macbooks or portable PC. Teachers for year 6–9 have been using Google classroom for tests, flipped classroom, evaluations and assessments and communication with students and parents, in the last two years. Teachers also use Google classroom for loading up videoclip and quiz connected to the school books. In addition, teacher platform Ping Pong is used by all the schools in the municipality. The school has a full time employed person supporting the teachers in the ICT environment. Students are not allowed to use their mobile phones during the lessons.

Among the 5 science, math and technology teachers, only one of them has taken a course in programming, but the course was not aimed at teachers in the school. Teachers are demanding a basic course for teachers who provide them with enough support to stand on.

3.4.2 Arduino

Arduino is a CPU (Central Processing Unit) on a board with a set of digital and analog connectors [4]. It is often sold as a kit together with various electronic components to enable the user to construct gadgets controlled by the CPU. A standard desktop or laptop computer is used to run the programming environment and to download the finished program to the Arduino board. Two teachers were having lessons in technology with 9 students working in groups of three in 8th class (15 years old) in lower secondary compulsory school. One of the teachers had been to courses in programming and the other teacher had not much experiences.

The assignment was to use Arduino kit to assemble electric devises to make a traffic light regulating the colored lamps by programming. The teaching has been stepwise, the students have looked at films about programming, they have got information about algorithm in their home language och constructed a wooden box in crafts. The students had earlier experience of programming in Scratch [71] and had also used micro:bit, a set of programmable electronic components [49], so they took very rapidly to the slightly more complex Arduino system. The activity using Arduino was a change from earlier experience using block coding for micro:bit to text-based programming.

The teachers linked the activities to the curriculum for compulsory school (Curriculum for the compulsory school, preschool class and school-age educare 2011, revised 2018., 2018) and technology subject matter; the aims of the subject:

- identify problems and needs that can be solved by means of technology, and work out proposals for solutions,
- use the concepts and expressions of technology,
  the core content of technology:
- Technical solutions for controlling and regulating systems. How mechanical and digital technology work together
- Technical solutions that use electronics and how they can be programmed.
- How components and subsystems work together in larger systems, such as the production and distribution of electricity.
- Words and terms used to name and discuss technical solutions
- Pupils' own constructions in which they apply control and regulations, including with the aid of programming.

The knowledge requirement for the grade passed (E):
Pupils can carry out very simple work on technology and design by testing possible ideas for solutions, as well as designing simple physical or digital models.
for higher mark (A):
Pupils can carry out very simple work on technology and design by systematically testing and retesting possible ideas for solutions, as well as designing well developed physical or digital models.

The purpose of the assignment was to get an idea, write an algorithm, troubleshoot, the code and solve the problem on the way to the product.

The students learned about concepts for text programming and repetition of electronics, which they already learned, for example LED (Light Emitting Diode), connector plate and resistor. The students compared block codes with text codes and had assignments to light the LED different periods and write the code. The students also had to find out how a traffic light function.

The challenge for the students were to find out how a traffic light function, write it down as a text followed by describing the function as an algorithm. In their report they had to write all the steps from the beginning, the mistakes they have done and the result. For example, one of the mistakes that several of the students did was the step to go back to yellow after the light was changing from red to yellow and green.

The teachers did not correct the students but let them find out about their mistakes themselves. One of the teachers 'goals was also to focus on the students' ability to troubleshoot. The students were given some algorithms that contained error that they should find and correct.
All the students were able to fulfill the assignment, some were faster than others. Other students did the assignment for longer time with the support of the teachers. Students thought that learning was more fun, more interesting and enhances motivation to learn. They also feel that their control over their own learning has increased as well as their grasp of English.

3.4.3 Bee-Bot

The teacher was teaching 30 students technology in 5th grade (12 years old). The assignment was to teach the students concepts of programming and learning the definition of algorithm. The teacher had no programming experience, but still took on the task of creating a lesson for her, using the Bee-Bot, a simple robot that can be programmed with push-buttons [7]. The teacher feels it is important to lay the groundwork for the understanding of programming by using physical objects to teach the concepts of loops and selection. The task given to the pupils was to write instructions for how to write programs for the Bee-Bot. use carpets for Bee Bot
I have worked with specific concept within programming. The students have seen a program on educational TV. We have discussed the concepts, and they have given examples and used Internetstiftelsen to give several examples of what the concept means. They did a written exam and an assessment of the 3–4 weeks. After having discussed the concepts for a long time, in the last lesson they should do the algorithm in several stations where they tested programming analogical. Here they might do a loop in one station and repeat, they should cut out arrows that they could lay on the floor to show how somebody could go to a certain place. Another station included programming of themselves. Two stations comprised Bee Bot. I have been concentrating on basic concepts.
The students thought the Beebot was a lot of fun, even if they were a little childish. All students were active, knew the concepts and could use them in the different stations.

3.4.4 PhET Interactive Simulations

PhET Interactive Simulations are a set of web-based applets to explore concepts in mathematics and natural sciences, developed at the University of Colorado [57]. They range in difficulty level from grade school to university studies.
A simulation of the ideal gas law was used in an 8th grade chemistry class. Also, how molecules in gas, liquid and solid are moving upon increase of pressure and temperature. Students should look at the simulations, write what they observe and describe with their own words. All students did not want to write down their observations.
The students were reported to have been enthusiastic and engaged in the exercise. Students that normally are bored and have problems to sit still and focus wanted me to do more lessons with simulations.

3.4.5 SketchUp

The technology teacher of his own accord used SketchUp, a web-based 3D-modelling application [1], letting the students design furnished houses. 30 students in 8th class hade lessons with one teacher in technology. Their assignment was to design and draw houses using SketchUp. They draw walls, doors, windows and painted the house. They could remove the roof and look into the house. The purpose was to turn the house

to view all sides and to measure. They also learned to use symbols. Using this kind of program makes it possible to work interdisciplinary with art, crafts and technology.
With the students chromebooks it took more time to draw. The students were very enthusiastic and worked long periods.

3.4.6 Tinkercad

The teachers had originally been requested to develop a lesson with micro:bit, but felt that they had insufficient programming knowledge to be able to use them effectively, and instead chose to work with Autodesk Tinkercad, a web-based 3D-modelling application [80]. They developed a lesson where the students had to construct a building with certain measures and then calculate the surface area of the structure.
Mathematics 30 students in 8th grade (15 years old), two teachers.
The teachers started the first lesson by rehearsing boundary surfaces. The task was to use Tinkercad to create a building without windows and doors using a cuboid and a prism and to learn scales and unit changes. The only prerequisites are that the cuboid should be 8 m long and 6 m tall. The students were supposed to look at all surfaces and calculate the area on all boundary surfaces. The teachers showed an instruction video from Youtube that the students could go back to if they wanted. One advantage was that the video could be seen both in Swedish and Arabic languages since many students had arabic as mother tongue. The video clip would give them information about how to turn the cuboid and how to go on with the program. As soon as they got stuck and did not know how to continue they were supposed to get back to the instructions published in Google classroom. The teachers or peers helped the students that got stuck.
We could make the instruction better for students that had difficulties by going stepwise.
The second lesson
Students' task was to learn how the volume of a cuboid change when the sides are changed. The students got instructions to write a hypothesis how the volume would change. When all sides are doubled the volume change 8 fold. Students had difficult to understand that the volume increase that much but when it was visualized using Tinkercad it was easier. The students that had difficulties with the program got more support this time. The instruction was more exact and stepwise from how to open the program and insert the numbers and the teachers were giving support to the students. In the beginning of the lesson, teachers were going through unit changes, how to calculate the volume of a cuboid and the units for area and volume, on the white board.

Most students were active and engaged in the task, some found it difficult and boring. Not working on paper was perceived negatively by certain students. Students who got stuck were either helped by peers who figured out how to solve the problem or re-watched the instruction video with a teacher.
The teachers felt that learning the software properly requires more time than the two hours spent.
The advantage is that the students were more active, and all students were engaged. The students were engaged in trying by themselves instead in lessons when the teacher make drawings on the whiteboard which students just repeat in their notebooks. Ii is like when they do practical mathematics using blocks to build and make observations. But here they do it using digital tools where they can look at all the sides of the cuboid. How will it be with the gable sides? The students sitting in front were happy and thought time passed quickly. It was the best lesson ever. But other students that had difficulties to put in data and turn

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the cuboid around. They gave up and thought it was the most boring thing they have ever done. They asked why they could not use a pen and paper instead. They needed more time to understand the program. Generally, the students were more active than they used to be.

In the second lecture students had difficult to understand that the volume increases before they used Tincercad, but it was much easier when it was visualized using Tinkercad.

On the second time the students worked more independent. We have learned that when students have difficulties we need to be more precise in what they have to do. To do practical exercises and se the conditions change gave increased understanding. The students that manage the task well the first time was independent but the teachers realized that they skipped steps in the instruction. They did not make hypotheses about how the volume would change, instead they started to calculate and to finish quickly. They had to start from the beginning.

3.4.7 Summary

The teachers reported that their students in general appreciated the lessons using digital learning tools, but it is not possible to tell if this was due to the novelty effect and to what extent the students have learned more or different things. Clearly there has also been an issue with the more complex tools requiring quite some time to learn to use, time which, in order to be cost-effective, should be amortised over several lessons using that tool for different things. Thus, e.g., Tinkercad should be possible to use for multiple exercises to be worth the effort. The teachers noted that it was not always easy to find a sensible use for a given tool, and asked for guidance on what tools would be useful for given situations.

4 Chapter 4 - Interviews

4.1 The interviews in Ireland

Colaiste Mhuire Co-Ed is a secondary school in Thurles, Co. Tipperary.

Please give a description of your school and your students.

Our school aims to promote ICT in education. It is hoped that every teacher would ensure their classes incorporate ICT in all, if not the majority, of lessons and because of this, students are encouraged to have their books on iPads. At present approximately 60% of our student body are iPad users, we are a STEM school and we run short courses in subjects such as coding, digital literacy and safety online.

Currently in our school we use an online system called Compass which allows management to organise daily schedules, timetabling and events and it allows teachers to track attendance, view student information including special educational needs and academic tracking.

Teachers reported that they like using ICT in the classroom, particularly younger teachers like Emma, JP and Katie as it is already an integral part of their teaching.

What are the school's goals for ICT use in teaching? What are your own goals?

Our school goals for ICT would be to be 100% iPad school and to eradicate technical issues such as poor WiFi connections or slow running computers.

Katie mentioned she would love to incorporate ICT more in Home Economics by including activities which allow students to become more independent in their learning and she has started to teach research skills because of this. This has made project work much better quality. She would also love, if she could, in the

future, have students take part in discovery learning and creating their own pieces of work through technology. She has begun down this path but would love to keep building on it.
Maggie's main goal for ICT would be able to switch between platforms, for example between her iPad and desktop, more easily. She also spoke about e-Learning, distance education, digital textbooks and virtual laboratories as the ideals of ICT use in science education. To add to this a number of teachers agreed that they often accessed ICT for their own personal learning and find that being able to access learning tools remotely allowed them to develop their own skill set in their own time, without having to adhere to the physical hours of a school or University.

Lynda made a very valid point that students are often more at ease with the use of ICT than teachers and that we, as teachers, need to be as comfortable as they are so we can best incorporate it where necessary. That being said, Lynda also feels very strongly about using ICT to maximise learning and not just for the sake of it. She looks to build on her work on Educreations, as per her case study to create concrete, manageable student revision aids.

Emma would like to be able to make and use more short video clips and animations to explain more complex topics and aid students learning by differentiating to a familiar medium. JP wishes to use more flash card/study note apps and display information from his iPad onto the whiteboard more easily as this is an area he is unfamiliar with.

JP's goal is to implement ICT as an additional beneficial learning resource, allowing students to become more ICT literate and keep up with an ever-changing world of ICT.

How do you currently use ICT tools in your teaching?

Maggie identified a number of apps she uses on a daily occurrence including YouTube, Google Classroom, Kahoot! and Microsoft Powerpoint, Excel and Word. She uses YouTube to show short video clips to enhance teaching and learning, Microsoft programmes to type notes, Kahoot! as a revision tool and Google Classroom to share information with students.

Katie uses Movie Maker to have students create their own videos on what they are learning, and all staff reported the use of ICT for research purposes for themselves and students in class. Lynda currently uses Compass, along with all staff, to take the roll, upload students grades and receive notifications from management. She has been teaching for 14 years, 3 of those years in this school, and it is the first school she has used google classroom in and finds it invaluable. The ease of uploading homework, notes, diagrams, videos etc. and the students can comment back on the work or ask questions.

Emma and all staff interviewed remarked on using ICT for assessment, from accessing past exam paper questions online, worksheets, generating word searches, printing templates for investigations or using Kahoot! Quizlet and Google Forms to question. All staff use Google for accessing school email, team drives, google classroom create slides or docs etc and use this platform to get students to share assignments and teachers can leave comments on the documents, suggesting areas of improvement, thereby providing feedback.

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Lynda uses Microsoft Word and PowerPoint regularly to create documents and different websites, such as Studyclix [61], Mentor teacher resources, Folens online [114], Kahoot and Educreations to access students' ebooks. Finally, JP prepares a range of activities and resources on a variety of software such as Google Classroom, email and Duolingo [59].

What ICT features have you found most useful? How do you use them when teaching?

JP and Katie found features for assessment such as Kahoot! and Quizlet useful because they are motivating and fun for students. They are challenged and working against the clock, sometimes with a peer so they enjoy learning. JP feels that interaction between teachers and students and students and their peers is vital in the classroom so sites such as Kahoot! provide a different approach from the direct teaching methodology. He also indicated that Google Classroom links many sites and allows for students to present work through a different medium.

Emma finds having iPads in class brilliant because students can use them for any activity, the only obstacle with this is making sure there are enough students in the class with iPads, ideally one each or one between two.

Lynda and Maggie find the Google platform, good internet access and access to YouTube most useful in their teaching. YouTube is ideal for showing a wide array of short videos on every topic imaginable. They spoke too about self-directed learning through guided research. Students are encouraged to enhance software literacy skills through Google Drive, Slides and Docs, for example when using Google Classroom they are able to encourage peer learning and communication in an educational setting.

What features do you feel to be missing? What would you like to be able to do?

Problems with internet connections and speeds were a recurring issue, along with lack of iPads for students and low numbers of school provided staff computers. Inefficient and/or problematic printers was also a huge hinder in our school which is why staff found online assessment tools to be highly useful as well as efficient and eco-friendly.

Computer rooms are in high demand in our school and Emma, Katie and JP would like if more computer rooms were accessible more often to students and teachers rather than being constrained to a timetabled classroom/lab. There is one school set of Chromebooks which can be very useful but are not always available if another class has them in use. Katie suggested that it would be great if there was a facility where students, especially those from less privileged backgrounds, could be given a digital device that is left at school to allow more children have some type of access.

Lynda would like more training in using Microsoft. She recently switched from using an iPad in the classroom for the past 7 years to a Microsoft Surface Go as she felt restricted with the amount she could do with the iPad and she saw other schools using the Microsoft tablet with great success. This is also an area Emma and Maggie expressed interest in and would be open to exploring.

JP is generally happy with Google Classroom as a storage medium and learning resource. However, storage limits for videos and voice recordings could be revised as it is not sufficient to store a whole class of

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recordings and recordings are an up and coming integral part of the new Junior Cycle (Irish national assessment) and Post Leaving Certificate (National assessment) programmes.

How do you rate your own knowledge of ICT tools for teaching? In what areas do you feel a need to improve?

Staff rated their own knowledge as generally good but with scope for improvement. Katie has completed ICT modules at undergraduate and master's level and enjoyed learning more about digital technology through these platforms. Emma and JP stated that they thought they would benefit from doing the Apple Teacher and Google Teacher courses in order to learn about how they could support more independent learning through technologies. Lynda and Maggie feel competent with their knowledge of ICT tools for teaching but remarked there is always room for further learning, especially with so much information out there. We would like to see what other teachers are using and find successful. One concern amongst staff was the safety and reliability of certain sites. A suggestion for improvement around this was a filtering process to be included on Google where only valid and reliable websites can be cited by students for exercises/essays.

4.2 The interviews in Italy

4.2.1 Liceo "N. Machiavelli"

Liceo "N. Machiavelli" is a very old secondary school in Florence open to different kinds of students. It offers four types of degrees:

- International Scientific and Foreign Languages
- Classical
- Economic and Social
- Human science

These types are very representative for the students who want to improve their skills in different branches of knowledge but they do not acquire technical skills.

Most of the students that choose our school are really motivated, especially those of them that choose the international courses, since they attend lessons 36 hours per week.

4.2.1.1 Interview n. 1

The teachers use ICT tools at school to help the students into competence and understanding the aims of the individual disciplines. The most used ICT tool is the Interactive Whiteboard, with its video and electronic board, by using video, sheets and apps from the Internet or created by the teacher.

I mainly teach science and foreign languages in high school and I use ICT firstly to catch the students' curiosity in a single unit of the module, secondly to help the understanding of the concept or experiment (searching video exhibits or lessons). Web apps could let some students improve their results or understand their misunderstandings.

Prezi [82] is a very useful tool, that allows one to create a presentation with ramifications. Very interesting, useful and suitable for both those who teach and those who learn.

I remember some years ago I used software with which I could create a physics experiment on the whiteboard using very simple objects, such as bars, balls, and springs and the student could see the results from changing the variables of the exercise. Unfortunately, I don't remember the name and I didn't find it.

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There are a lot of apps that the students could use to determine maths equations or inequalities, systems, etc (e.g. Photomath [78]) or that give the possibility to draw functions (e.g. GeoGebra [40] or Grapher [115]).
Lots of these apps or web apps are implemented in Javascript language that is not very simple to practise.
Probably we need an analytic list of apps to use and a compendium of how and why we could use some app in school.
I do not use ICT tools so often, the school system in Italy requires lot of modules and units for all disciplines so the time at disposal for each teacher is not a lot and the time to spend to use ICT tools is very little.
If I could choose, I would prefer to have tools that require active participation by the teacher and that students can replicate at home, summarize what they have learned to present to their classmates.

4.2.1.2 Interview n. 2

The aim of the school for the use of ICT in teaching is to promote a personal and active construction of their knowledge by students, starting from their needs and motivations, actively collaborating with classmates and teachers. I am a science teacher and my students are from scientific courses, so I use ICT tools to increase student participation and involvement, but above all to create learning situations that develop critical thinking and also a scientific attitude towards the problems and issues of people’s lives.
During the daily lessons I often use ICT to increase student participation and facilitate the learning of subject content, but much more at the end of each teaching unit to encourage students to acquire strategies to manage information, structure it and reflect on them critically.
During daily lessons I mainly use an interactive whiteboard, which allows to interact with the contents directly on the screen and thanks to the possibility of connecting to the internet, it allows to download materials directly from the network; the software's storage capacity allows to save each lesson, to be able to use it in subsequent moments, to be able to print it, to be able to share it, to make a documentation of the progress made.
At the end of a teaching unit I use different ICT tools depending on the goals I intend to achieve. The students do not usually have knowledge of the historical development of science and do not know how to place the most important discoveries and acquisitions in a temporal dimension nor a single scientist in the age in which he lived. It is important that students create their own mental representation of the temporal sequence of science and for this purpose I use the construction of “timelines” as a valid aid. Different time line production tools are available online such as “Time Maps” and “Free-Timeline” [38].
I sometimes use “online laboratories” to overcome the limited availability of time, sometimes to overcome the lack of traditional laboratories adequately equipped to perform specific experiments in chemistry and natural sciences or to simulate natural phenomena that cannot be reproduced in the laboratory.
Video production remains in my teaching a very important collaboration activity. Students are very good at filming with mobile phones educational tutorials, small scientific experiments made by the students themselves, educational visits, extracurricular activities and then discussing them together. Filming is often not of quality but has the flavor of spontaneity and authenticity.
To generate collaboration among students and to promote collaborative learning from this year for two classes I use the platform “We School” where I created virtual classrooms in which the students share all files lessons, documentation and the single or collaborative production (timeline, video, ppt, maps etc). The platform is also useful for evaluating both individual and group learning performance. To this purpose I can create, thanks to Google Drive, online tests with automatic and instant correction and publish them in a

"notice board" inside the platform. Students can do this simultaneously and immediately know the correct answers and the score obtained: immediacy reinforces the correction of errors.

The ICT tools in teaching have required and take a long time at the beginning to be acquired and perfected in the classroom, but once adapted to my educational needs they are not only compatible with the time needed to carry out school programs but they support me in the teaching and make me feel closer to my students. I would like to create in this project a platform in which teachers from my school and from other Italian and non-Italian schools, share ICT goals and tools (apps and sites for ICT resources etc.), organize scientific experiences conducted by students in "remote laboratory" mode. Furthermore, it would also be useful to share space among students from more than one school. ICT also allows distance sharing, expansion of school time and shared production.

I did some training for digital education, but I would like to acquire specific skills in the use of ICT in science teaching.

4.2.1.3 Interview n. 3

Teachers began to use ICT tools since the first Smart boards began to be spread school wide. Smart board helped teachers in their daily lessons, giving the chance to save and store didactical material to be recalled according to each specific educational project and overall it helped students to easily learn the main concepts of the subjects. Furthermore, the use of ICT in the didactics for students with special needs let them to approach learning more easily, thanks to specific app or software (e.g. Cmap [14]) to create visual and conceptual framework especially in case of dysgraphia or such learning disorders that affects working memory.

My classes are mostly from scientific courses and I don't use ICT daily, since we have to strictly fulfil shared objectives to make students ready to face the final diploma exam which requires specific ability in solving problems prepared by the public education ministry and that are the same all over the country. Time is not enough to combine new didactical approach by ICT and to make students able to practise the ability to solve problems by their own.

It happens that I show video or animation related to some topics in order to make students deeply understand them.

I also suggested some video lessons from Youtube to substitute my lessons, in the spirit of flipped classroom methodology to have more time to apply what students learned at home watching the videos with the students at school. Students really appreciated this kind of approach to new topics.

A very useful tool I use in the first classes and warmly suggest is Schooltoon [90] because I found that cartoons are funny but well made, well balanced between a friendly but a rigorous approach to fundamental algebra topics.

It is also very useful to break down some prejudices since it proposes the typical class situation with the bookworm student, the worst student interested to anything but that at the end of the lesson has always some good exploit and the pretty girl who's is usually not considered smart but that instead is witty and brilliant, giving the chance then to get a double result: catching students' attention and make them curious towards mathematics and facing some stereotypes that sometimes exist in the society, not only at school.

Very useful is also Geogebra [40], that is dynamic mathematics software for all levels of education that brings together geometry, algebra, spreadsheets, graphing, statistics and calculus in an easy-to-use single package.

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I find that using ICT requires more time to prepare lessons and to use them during school-time, so I think that teachers need to better know the available software and need to receive proper training in order to get familiar with the major available software.
I don't think I have a satisfying knowledge of the available ICT for education and I feel the necessity of being better informed and trained about them, in order to use more frequently in my didactics and to involve students more to benefit from them on their own, in the specific field of Maths and Physics.

4.2.1.4 Interview n. 4

The teachers use the ICT tools daily to help the students to better understand some topics. The most widely used ICT object is the interactive whiteboard, which uses videos, sheets and apps from the internet.
My classes are mostly from human sciences. I use ICT to help my students to better understand some of the topics studied, investigate or fill in any gaps.
Above all I use interactive simulations to better understand how physical phenomena occur and to perform some simulations of physical experiments. I sporadically use applications like GeoGebra [40], Plot Function and Equation editor of the Word program [66]. I often use tables, functions and graphs of the Excel program [66]. I often use the Powerpoint program to make animated presentations [66].
I think it may be useful to have available, an analytical list of apps that best explain how it works in application to the different topics to be treated to make a more focused and constructive use.
I do not use ICTs as much as I would like because the Italian school system focuses on a broad teaching program that leaves little room for "experimentation" and the use of apps.
If I could choose, I would prefer to have tools that require an active participation of the teacher and that students can replicate at home.

4.2.2 Liceo Mazzini

Liceo Mazzini is a secondary school in La Spezia.

Please give a description of your school and your students
Humanities and Language High School.
Number of pupils 849
Number of classes 41
Average pupils/class 20

What are the school's goals for ICT use in teaching?
In order to understand the choices in ICT teaching within the school, it is necessary to briefly reconstruct and contextualise the paths taken by the school. Therefore, I think it is appropriate to underline some peculiar aspects of the school, which in some way represented the cultural substratum in which this school has operated:
- For years, the school has taken on board the ministerial and regional indications, becoming the promoter of various initiatives aimed at strengthening and applying digital technologies, such as, for example, the construction of computer labs, the promotion and organization of digital literacy courses.
- The significant and growing number of students, the various fields of study, the complexity of administrative management have amplified the issues related to the applications of digital technologies in various areas, immediately highlighting the potential and critical, such as, for example, operating costs,

maintenance and obsolescence of machines, the lack of laboratories in relation to users and the growing demands of teaching, the need for a network technology that supports these needs.
- From a purely didactic point of view, in recent years the skills of many teachers in the use of ICT have matured and profitable synergies have been activated. In school culture, teamwork is considered a resource. In addition, there is a strong belief that interdisciplinary and transversal skills in teacher collaboration are a resource for pupils.

What are your own goals?
I see ICT as a facilitator of communication and a stimulator of students' attention, as a means of making explanations more engaging and “fun”.
Precisely because ICTs are “part of young people's lives”, I use them to achieve good effects on the acquisition of skills, such as the ability to discern and criticise the wealth of information or even the ability to synthesise.
I use ICT with students with learning difficulties because I am convinced that they improve their learning.

How do you currently use ICT tools in your teaching?
I use ICT and teaching technologies to:
- facilitate learning for students with learning difficulties;
- share content and ideas (internet, forums, emails, social networks)
- make the subject more attractive (interactive whiteboard, laboratory, etc.)
- organisation of teaching and communication with students and families (electronic register)
Teaching skills play a central role for me: I try to capture the attention and stimulate the imagination, while maintaining a strong leadership role.

What ICT features have you found most useful? How do you use them when teaching?
ICT can offer students different, and sometimes even more effective, opportunities and ways to achieve a specific educational goal.
They allow for a creative approach to different educational situations.

What features do you feel to be missing?
I do not have such a deep knowledge of ICT and educational technologies to answer this question.

What would you like to be able to do?
I would like to create an educational learning environment in which students, through cooperative relationship processes, can proceed to the negotiation and construction of their knowledge, valuing learning styles and personal profiles of behaviour.

How do you rate your own knowledge of ICT tools for teaching?
I think it is important for me to have the opportunity to follow training courses and continuous updating. The evolution of ICT and educational technologies is so fast that it requires continuous attention. At the moment my knowledge is completely partial (30%).

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In what areas do you feel a need to improve?

In the design with the use of ICT and in the production of teaching materials.

4.3 The interviews in Sweden

Ronna school is a 0–9 grade school in Södertälje, a town south of Stockholm.

The interviews have been performed as focus group interviews with participants as listed for each interview.

4.3.1 Focus group 1

Participants	**Subject**	**Level**
MTA	mathematics	Lower Secondary school
MTB	mathematics	Lower Secondary school
ST	science	Lower Secondary school
TT	technology	Lower Secondary school
HM	Headmaster	

Interviewers: three senior lecturers from Södertörn University.

Introduction: In the first focus group interview, four teachers participated (two math teachers, one science teachers and one technology teacher), all teachers from upper primary school. At the meeting, the headmaster of the school also participated. The interview focused on an inventory of the teacher's digital practices and their experiences with ICT and digital technologies in their teaching practice. The discussions revolved around questions concerning infrastructure and the teacher's everyday use of ICT and digital technology in teaching. The questions discussed regarding infrastructure ranged from an inventory of access to ICT and digital platforms and tools, to support, and for the school's administrative structure. Questions regarding the use of ICT and digital technology concerning their attitudes towards using ICT in teaching, and how their use unfolds in their teaching practices at this moment, were discussed. The interview ended with a short workshop focusing on the teacher's positive experiences using ICT and digital technology in their teaching practice, problems and challenges that the teachers identified, as well as visions and best practices that they can see using digital technology in teaching practice.

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Summary of focus group 1: All teachers have their own computers (*MacBook* and *PC*) with administrative rights. The students at the school also have access to own computers (*Chromebook*) and tablets (*iPads*) provided from the school (school year 6–9, age 13–17). The choice of computers and hardware is related to economic concerns, administrative rights, open access, as well as an equality concern for the students' rights to access to technology. The school has a full time employed person responsible for the support of their ICT environment.

The sharing of material files between teachers and students was done by using *Google Classroom* [1]. However, soon (at the end of the spring term) the school will change to *Office 365* [66], due to their lack of user agreement for *Google Classroom.*

As teaching platform, they use the service *PingPong* [79], but will change to *Vklass* [111], which is compatible with *Office 365*, during the upcoming summer. However, the changes that they mention are always related to procurement and the HM argues for these changes by relating to the students' forthcoming studies at upper secondary school, where they will use the same platform. The procurement that concerns the change of teaching platform is governed by the municipality and will include all schools in the municipality. The changes of, for example, teaching platforms, always take place during the summertime, so that the teachers have the opportunity to prepare for the school start in the autumn term. One of the teachers (MTA) is well involved in the administrative concerns and how the changes can be governed by the teachers' teams and in their planning.

The teachers have not yet tried to do online exams for their students on the *PingPong* platform (ST). However, they mention that in other subjects at the school they have used automatic exams by using *Google forms* [43], and that these exams can be self-corrected, and thereby be a part of the teacher team's formative teaching practices. The fact that they do not yet use online exams seems a bit contradictory, due to the fact that they also mention during the focus group interview that they use digital exams in maths.

The teachers mention a specific rubric for knowledge requirement, a commercial digital tool that they have used within the math subject for a year. The tool is frequently used in their teaching practice (MTA). In the math subject they do digital exams in a commercial service called *ExamNet* [37]. This digital service is used in other subjects and the exams are also self-corrected (MTB). The school has bought the services *ExamNet* and *Kunskapsmatrisen* [55]*,* and they are used for creating rubrics, promote links to other teaching materials, such as further readings, digital exercises, video recordings of lessons, and self-assessment tests (MTA). The teachers can also see the results of the students and develop their knowledge further. These tools can be used also in other subjects, but is mainly used in the math subject. The teachers highlighted the potential of these services to follow the students' knowledge development, and the possibilities to make assessments both by the students and the teachers.

Studi [100] and *Kahoot* [53] are used as digital teaching tools for being able to quickly measure knowledge, or to do simple quizzes during lessons mainly in natural science (ST). Tools for interactive practical simulations within natural science is mentioned as a desired tool (ST). The

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teacher expresses that it is difficult to do practical experiments in the classroom with 30 students, which leads to more theoretical teaching practices within these subjects. The consequences are that they do less practical experiments in natural science but they still have to achieve the knowledge requirements according to the school's curriculum (ST).

Mentimeter, *Mattebah*, *Kims matematik*, *matematik.com*, *matte.se*, *matteboken.se*, and *Studi* (videos and quiz), are mentioned by the math teachers as tools that they use on a regular basis. The favorite tools mentioned are *matte.se*, and S*tudi*, due to the possibility to translate the content into various languages necessary in this specific school environment. The teachers also address that it is the needs that govern the choice of tools in their teaching practice (MTA). The math teachers also brought up that they desire tools (MTB), time, and competence development for being able to use programming in their teaching, as this is their greatest challenge at the moment (this challenge also applies to the science and technology teachers).

Since programming was introduced in Mathematics in the curriculum for compulsory school, the formative aspects of the teachers digital teaching practices, are raised at several occasions by both the HM and the teachers. This is prompted as an important goal in the school and something that they work with in all the teacher teams at the moment.

The teachers also have discussions about the use of digital exams and mention that students doing digital exams are often skeptical at the beginning. The teachers need to explain why they use these kinds of services for exams, often referring to that this kind of exams are used in the upper secondary school. One aspect that the teachers also raise in relation to this, is that the student's skepticism also comes from the fact that they cannot use handwriting when doing digital exams. The students are used to do this and prefer to do exercise in math by hand. The teachers express that they do not have any resistance to use digital tools for exams, but they raise the question that they need time to learn both the structure of the platforms and how to use them in the teaching practice. They also express the advantage of being several teachers in the team when learning how to use a new digital tool in teaching.

In the interview the relation to the student's parents evoke. The teachers mention that many of the parents of the students do not have or use email, and that several parents do not have identification for using online bank services, or Swedish identification numbers, that makes the information from the school teachers rather difficult. This leads to that the parents use their children's accounts (that they use in the school) to access information about the student's knowledge progress, and to get information about what their children do in school. The teachers use blog services to communicate with the parents, where the parents can translate all information into various languages, and also get access to own personal log-ins to access the information provided.

Regarding mobile phones in the school, the HM informs that the student's mobile phones are collected at each lesson in a so called "mobile kindergarten", however, there are some teachers that use mobile phones in class to evaluate teaching lessons etc., and also some students use mobile phones to listen to music for better concentration during class. The HM, however,

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addresses that the proposed governmental mobile prohibition would be difficult to execute and that the school does not advocate this kind of regulation, even if they aim to keep the lessons mobile free at the school.

The final workshop session during the focus group interview, resulted in the most positive experience and potential with digital technology in teaching brought up being that; finished material saves the teacher's time, students gain more knowledge, it is good tools, it is time efficient, it promotes formative teaching, the students love digital tools, it is seen that the subject becomes more fun by switching from old methods, it is pleasurable, it promotes quality assured teaching, it leads to preparation for the future, and it opens up for site-independent teaching.

The problems and challenges brought up were; that bring your own device should be the rule, that the choice of system should be open, problems with filters, messy internet connection, computer problems, that it sometimes takes a long time, the lack of skills and knowledge, that it takes time to learn new tools.

The visions for using digital technology mentioned by the teachers were; that the students do not want to leave school, redefined learning, that the students reach their full potential, smart boards for experimentation, studies elsewhere than in school, and to develop programming competences.

4.3.2 Focus group 2.

Participants	**Subject**	**Level**
MTA	mathematics	Lower Secondary school
ST	science	Lower Secondary school
TT	technology	Lower Secondary school
T	mathematics, science	Primary school school, year 4–6

Interviewers: two senior lecturers from Södertörn University.

Introduction: In the second focus group we interviewed three teachers from lower secondary school (one math teachers, one science teacher, one technology teacher) and one teacher from primary school participated. The second interview focused on group discussions initiated by various dream scenarios by the teachers at the end of the final session of focus group 1. Based on their statements regarding their positive experiences and the problems and challenges that they highlighted regarding the use of ICT and digital technology in teaching practice, as well as their visions and best practices, four scenarios where created and presented as basis for the

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discussions. These four dream scenarios included situations of being able to perform teaching at other places than the school (both physical and digital), being able to test programming exercises with the students without any further education or experience in programming practices, pleasurable and joyful learning, platform independence and open source solutions for the school's digital platforms and services.

Summary of focus group 2: The second focus group started with discussions regarding how the teachers use digital tools in the various grades of the school, mainly how the change looks like between going from primary school to lower secondary school. In the primary school, students do not have access to computers or tablets to a great extent, while the access to computers and digital technology, both for teachers and students, in lower secondary school is more developed.

During the focus group and the discussion around the four dream scenarios it initially revolved around situations of being able to perform teaching at other places than the school (both physical and digital). The teachers highlighted the importance of this as planning, scheduling, time efficiency, to visit the new place with smaller groups easier to handle as a teacher, to be familiar with the place before taking the students there, and not the least, extensive and detailed planning of examination and exercises to perform at other locations. One of the teachers however highlighted the importance of letting the students be free to explore the new place at the first visit, either physical or digital. This stimulates the desire to discover what the new environment affords (T). The teachers also promote the importance of continuity, both regarding the frequency of visits and taking the same group of students each time. Issues such as economics and transportation were highlighted as the most important reason why the scenario of having lessons on other physical locations is problematic, were also brought up in relation to the problems of planning and scheduling. For the students the teachers mention that interest and the elaborative aspects of being in another location would give the students inspiration and desire for gaining new knowledge, and to see other realities than the school and its localities. Visiting digital museums as a way to enable the same experience for the students would be much easier for the teachers, as it demands less planning and scheduling, and is much easier for the teachers to familiarize with in beforehand. Group exercises where highlighted as a good way to approach digital localities such as museums and explorative 3D environments (ST). However, the teachers view this kind of environments as complements to visiting physical localities, and insisted on the importance of being away from school physically.

Secondly, the discussions about being able to test programming practices with the students without any further education or experience in programming practices, mainly showed the lack of knowledge and needs for developing further knowledge. The teachers meant that they need to learn programming before approaching it in their teaching practice. Especially one of the teachers express that they cannot do anything that they do not feel secure with (MTA). Another teacher meant that they need basic knowledge about algorithms, but that they do not need any deeper knowledge about programming to be able for example to work with block programming in *Scratch* [92] or other similar environments (TT). The teachers also describe that if the students have at least one teacher that has the knowledge of programming together with the students it is enough for creating an interest based on what they can build further knowledge on. They also thought that the students would gain desire to create new solutions to problems. One of the teachers highlighted that the students also need basic knowledge in electronics (TT). By combining this knowledge with programming and electronics they could make progress in using programming during lessons. Programming is highlighted as time efficient, pleasurable, and a possible way of working with several skills at the same time during teaching.

Thirdly, in the discussion around the scenario of pleasurable and joyful learning, the teachers highlighted the need of challenging the students (TT), promoting curiosity, and also the need of supporting the students in making the lessons enjoyable for the students (MTA). Bad patience of the students was a problem brought up by teachers (T), that hinders pleasurable and joyful learning.

At the end of the discussion we demonstrated physical artifacts, platforms and tools such as *Tinkercad* [105], *LittleBits* [62], *Bee-Bots* [7], *Arduino* [3], *micro:bit* [65], and *Raspberry Pi* [85], and the teachers reacted to the various artifacts while discussing how they would approach them in their teaching practice. Some of the tools were familiar to the group, while some were new to them. They were curious and asked questions on how to use them in class, what they usually were used for and how they function. One thing that was brought up during the discussion was the importance of tools to trigger interest without being regarded as childish by the students that have experience from using similar tools at home. This discussion ended the second focus group interview.

5 Similarities and differences between the countries

5.1 National policies

All three countries involved have a very strong governmental commitment to the introduction of digital competence in the curriculum. In Ireland and Italy this is backed by large national investments in infrastructure and computing hardware. Swedish schools being the responsibility of individual municipalities have a larger variability in how much different schools invest in digital technology [97, 98].

In Sweden and Ireland relevant authorities have made efforts in creating web sites containing teaching materials to use in the classroom, and all countries have recognised the need for continuing professional development for teachers.

5.2 Experiences with digital tools

The partner schools mention a wide range of tools, but the ones mentioned more than once are Google Classroom [1], Kahoot [53], and Mentimeter [50]. These are fairly generic platforms, Kahoot and Mentimeter both intended for generating quizzes in order to rapidly check on the students' understanding. Google classroom is an administrative tool allowing teachers and students to supply and update information, which is seen as extremely useful.

Many schools seem to use iPads and Chromebooks as being suitable devices, ideally having one per student, but there are concerns with low network bandwidth and general unreliability of web sites and hardware. In Ireland, while there are no official figures on how many schools are using devices, Wriggle – one of the largest firms supplying iPads to schools – manages up to 40,000 devices for students in more than 100 secondary schools. The Professional Development Service for Teachers (PDST) - Technology in Education provides advice to Irish teachers on the use of hardware, software and training for digital competences.

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