INQUIRY-BASED SCIENCE EDUCATION AND E-LEARNING

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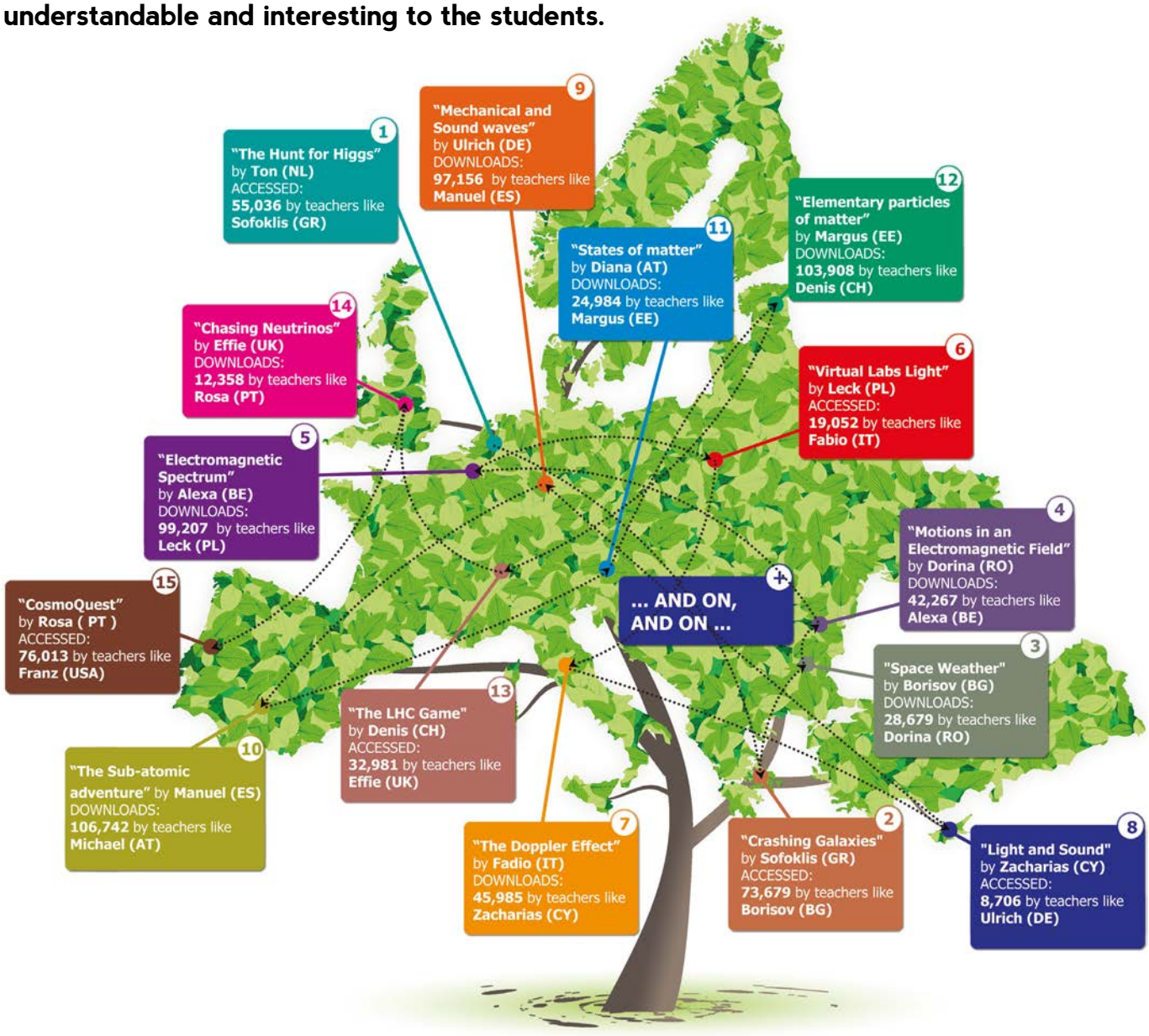
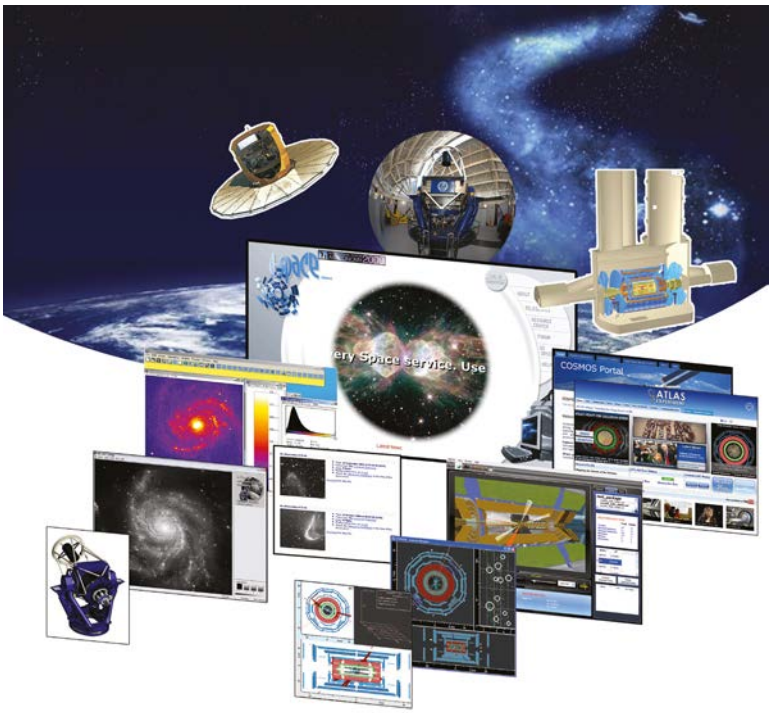
Science classrooms (even in the time of the pandemic) should provide more challenging, inquiry-based, authentic and higher-order learning experiences allowing students to participate in scientific practices and tasks. Rich scientific databases, e-Learning tools and digital educational resources can serve as a catalyst for science learning. They can offer a better understanding of complex scientific research, making science understandable and interesting to the students.



Science Education and Inquiry Approaches

Science education methods (project-based, collaborative, and hands-on) are highly affected by the current restrictions that have been implemented in schools due to the COVID-19 pandemic. Even in a hybrid scheme of delivery of education services, the restrictions posed are creating a rather problematic framework for the implementation of *inquiry-based* projects and activities. On the other hand, the introduction of *inquiry-based* approaches into school curricula is a major priority in most EU Member States. *Inquiry* is seen as the catalyst for the development of students' deeper learning competence (academic knowledge, problem-solving skills, cooperation and creativity, development of academic mindset). *Inquiry* holds great potential for increasing the enrolment and academic success of students, addressing gender segregation and producing a well-qualified and diverse workforce with the right Science Technology Engineering and Mathematics (STEM) skills [1]. How can we safeguard the continuation of such initiatives? Are there tools and applications that could facilitate the implementation of *inquiry-based*, collaborative and creative activities while schools are closed? Are teachers and schools ready to deploy such innovative approaches to keep delivering high-quality services to their students?



▲ **FIG. 1:** e-Science programmes that reinforce the cooperation of leading researchers provide a solid framework for bringing new instruments and opportunities into modern education, thereby providing learners with better opportunities to build their knowledge for the future. e-Science programmes provide an appropriate framework for reinforcing a participatory learning approach and developing instruments for authentic assessment in science education at all levels. Discover the COSMOS Portal [2] offers access to such programmes related to High Energy Physics, Space and Astronomy.

The unique potential of e-Learning

E-learning represents an appropriate vehicle to overcome these barriers and to offer high-quality science education, while at the same time safeguarding the key characteristics of physical learning through the *inquiry* experience. The orchestrated use of digital resources, applications and tools can facilitate the development of innovative learning experiences that do not merely simulate the school lab environment. They can offer much more than that: access to virtual labs and online experiments that cannot be performed in school labs, e-Science programmes for schools that include virtual visits to research infrastructures (see Figure 1) [2], virtual pathways to science centres and museums located all around the world. Furthermore, the introduction of innovative digital tools that enhance experimentation, *e.g.*, the development of digital storylines, enriched with 3D digitization and AR/VR applications for the students, tap into the creative potential of technology to offer transformative experiences for schools (see Figure 2) [3].

Such experiences focus heavily on skills development, deepen conceptual understanding and succeed in introducing concepts within their real context. The real key to future developments in learning is personalization: of interpretation to significantly enhance social and intellectual inclusion; of technology to free both schools, teachers and students from many of the current constraints; of learning to finally facilitate an escape from the deficit models so prevalent in schools and release untold potential, as the individual learner is able to use technologies to exercise choice and to take responsibility for his/her own learning. For example, students can navigate the finest digital collections at European science centres and museums, guided by attractive educational pathways connecting objects to discoveries. Digital collections at science centres and museums can form interactive storylines, interconnecting the school curricula with different exhibits, beyond time and location limitations. E-learning provides innovative ways to explore the world: not simply to automate processes but to inspire, to engage, and to connect. It offers a powerful framework for teachers and students to engage, discuss and explore how schools need to evolve, transform and reinvent; how schools can facilitate open, more effective and efficient co-design, co-creation, and use of educational content (both from formal and informal providers), tools and services for personalized learning and teaching; how schools can become innovation incubators and accelerators.

Effective introduction of *inquiry-based* approaches into educational settings to promote learning outcomes

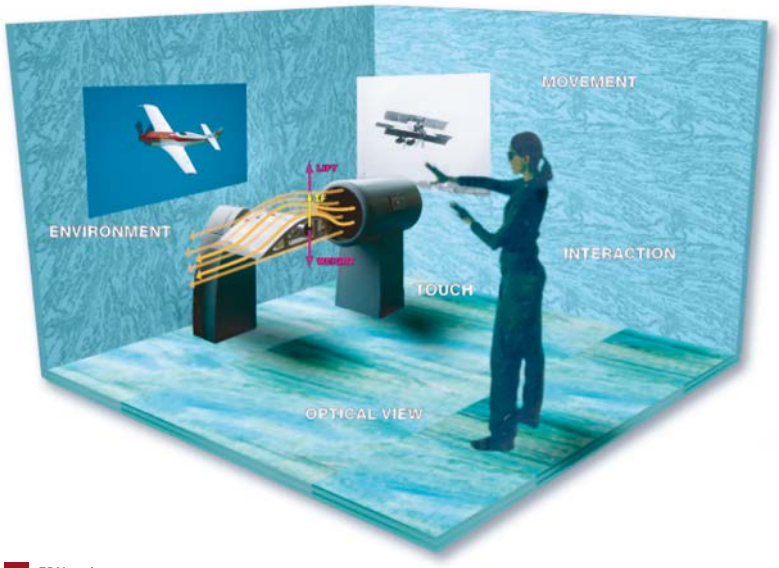
Inquiry-based approaches in science lessons have produced positive educational outcomes even over the long term [5], [6], [7]. Although the process itself is time-consuming and the current curricular structure too often fails to support opportunities for such interventions, digital tools and resources offer an effective way to decrease the time needed and ● ● ●

• • • to encourage teachers to adopt the *inquiry* process in their daily lessons [7]. Organising and delivering digital resources during a normal school lesson is quite a demanding task for teachers and prevents many of them from following such an approach. Technology-supported, teacher-generated lessons enriched with high-quality educational resources could bolster such interventions in a variety of classroom settings, meeting the needs of both students and teachers [7]. Such interventions could be effective in building bridges to real life experiences, but also lead students to a lifelong learning experience, and inspire students – even those with limited interest in science and math subjects [8]. The teachers' role concentrates on organizing learning resources to run collaborative activities amongst student peers and make use of existing lessons [9]. It is exactly this competence-oriented, *inquiry-based* lifelong learning experience that facilitates teachers' and students' interaction with 'knowledge scaffolds' in their peer communities by sharing (knowledge) domain- and (education) grade-specific practices and solutions.

Creating Deeper Learning Experiences

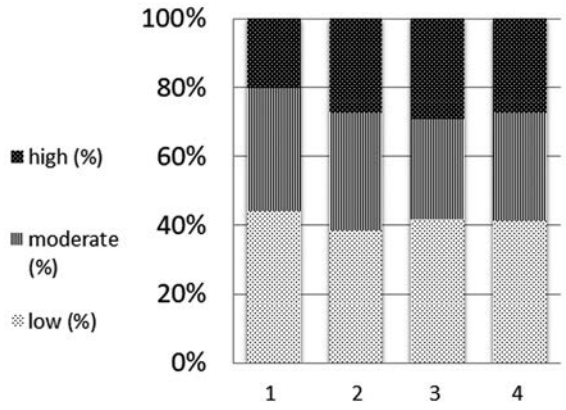
Advanced e-Learning tools are making assessment more efficient and effective, incorporating the added capability of administering dynamic and interactive problems, engaging students' interest more fully and capturing more information about the problem-solving process. This result also is definable as deeper learning, which is regarded as sustained retention of successfully acquired cognitive knowledge. ICT-based assessment tasks can make it possible to record data about the type, frequency, length and sequence of actions performed by students in responding to items. The organisation of *inquiry* activities in lab work provides the opportunity to analyse the effects of advanced scenarios that foster complex problem-solving abilities. The different steps performed by the students in the *inquiry* process (*e.g.*, understanding and characterising the problem, representing the problem, solving the problem, and reflecting and communicating the solution) can be included in the educational design process: in this way, the system allows for the mapping of changes in these partial abilities during the problem-solving process. The assessment permits the analysis of solution paths or strengths and weaknesses at an individual student level. The Inspiring Science Education EU Policy Support Action [3] has performed such a study with the involvement of more than 12,000 secondary school students (14-15 years old) in *inquiry-based* science lessons using an advanced e-Learning platform for their delivery. The analysis of the data demonstrates a significant increase in high achievers (20-29%, compared to the 10% OECD average) while a significant impact on low achievers is also recorded (see Figure 3) [10]. The potential to overcome the usual barrier to implementing *inquiry-based* lessons in classrooms is shown by the substantial increase of the proficiency level within complex problem-solving tasks. Conclusions regarding the domain-specific characteristics of the curricular content may be drawn; for instance, whether a student has attained a certain competence level after a specific science activity. The acquisition of increased levels of problem-solving competence provides a basis for future learning, for effective participation in society and for performing personal activities. Students need to be able to apply what they have learned to new situations. The study of individual problem-solving strengths provides a window on their abilities to employ basic thinking and other general cognitive approaches needed to confront life challenges.

▼ **FIG. 2: Visualizing the invisible at science centres and museums: The visualization of natural phenomena could support conceptual change. Immersive interfaces can foster educational experiences that draw on a powerful pedagogy: Situated learning requires authentic contexts, activities and assessment coupled with guidance and mentoring [4].**



Re-imagining Science Education

A wide range of innovative ideas has emerged in science education over the last few decades. While progress has been made in implementing them, much opportunity remains, especially as the needs of our economy, our insights into pedagogy and the emergence of affordances such as e-Learning have evolved. However, innovations also have side-effects, if they are not widely propagated, of widening achievement gaps. We must ensure that the tide of innovation 'lifts all boats'. The fact is that the COVID-19 pandemic has accelerated matters dramatically. Schools and educational institutions with the wherewithal to respond to COVID-19 – be it through e-Learning or hybrid teaching – have been forced to accelerate their innovation. It is important, as society limps back from an extended abnormal, to reflect on what has worked and what has not, and to ensure that the overall outcome of this difficult period in human history is a set of practices that are better suited to serve overall progress rather than jury-rigged solutions that live on because they are convenient. The COVID-19 era has offered us opportunities to re-imagine science education. ■



▲ **FIG. 3:** The graph presents classroom profiles as far as the students' proficiency in problem-solving competence is concerned. The study includes data from 12,000 secondary school students (14-15 years old) who were involved in inquiry-based science lessons using the Inspiring Science Education platform for their delivery. The average pattern of high, moderate and low performers per phase of all students, for all implementations in the pilots. Phases: 1 = understanding and characterising the problem; 2 = presenting the problem; 3 = solving the problem; 4 = reflecting and communicating the solution. The analysis of the data demonstrates a significant increase in high achievers (20-29%, compared to the 10% OECD average) and significant impact on low achievers (decrease from 45% [OECD Average] to 40%) after their involvement in the inquiry lessons.

About the Author

Sofoklis Sotiriou is the Head of Research and Development Department of Ellinogermaniki Agogi since 1998. His main field of research is the modernization of science education using the *inquiry-based* approach. His work is focusing on the design, application, and evaluation of virtual and digital media environments that bridge the gap between formal and informal science learning. He is the author of the Science Textbooks that are used in Greek primary schools.

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