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The science curricula for ages 11-12 across the European Union: A comparative analysis

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ABSTRACT

The impartation of scientific education is important in shaping the cognition and skills of young scholars, particularly those in the 11-12-year-old age group. The diversity of educational frameworks and cultural phenomena in Europe results in a wide range of science syllabi for this specific age group. This manuscript undertakes a comparative analysis of these diverse syllabi, exploring various methodologies in curriculum development, didactic strategies, evaluative mechanisms, and integrating technological tools with empirical experimentation. The goal is to identify the most effective practices and potential areas for enhancing students' scientific and academic journey in this age group.

Keywords: science, curricula, primary education, European Union, 11-12-year-olds

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INTRODUCTION

Research has revealed that there is no uniform science curriculum for students aged 11-12 across all member states of the European Union (EU) (Greif et al., 2021; Mikac, 2021). Each member state is primarily responsible for its education policies and curricula (Keating et al., 2009), leading to significant variations between nations.

The EU is resolute in advancing the importance of science, technology, engineering, and mathematics (STEM) education (Bybee, 2013). This dedication is seen in its many inspiring initiatives for education and innovation. The EU promotes STEM education and offers significant support and money for programs to improve STEM education and promote European innovation and competitiveness (Tytler, 2020).

An important project of the EU is the European framework of key competencies for lifelong learning. The framework delineates eight essential skills for achieving personal satisfaction, integrating into society, actively participating in social activities, and securing employment (Ferrari, 2013). 'Science understanding' is a crucial competency that involves knowledge about the universe's physical and biological aspects and the capacity to understand and explain scientific occurrences (Ortiz-Revilla et al., 2020). The EU's unwavering focus on essential skills, particularly 'science understanding', highlights its commitment to promoting a comprehensive education.

It is essential to highlight that the EU's commitment to STEM education is not just rhetoric. The Horizon 2020 program, which was the EU's financial program for research and innovation from 2014 to 2020 (replaced by Horizon Europe for 2021 to 2027), has provided active support to several initiatives that seek to promote STEM education and include young people in scientific activities (Pacheco-Torgal, 2014). The demonstrated history of assistance should instill optimism for future endeavors.

While the EU offers assistance and recommendations for educational policies and initiatives, particularly in scientific education, each member state has the ultimate authority for determining specific curricula and educational practices (Sultana, 2004). Consequently, the details of the scientific curricula for kids aged 11-12 differ from one nation to another (Hartley et al., 2020).

The science curricula for children aged 11-12 in Europe are structured around specific thematic axes determined by similar educational aims and trends. Tammaro (2007) and Priestley et al. (2021) have identified these axes.

1. Principles of basic science: Most European curricula include essential scientific ideas such as forces, motion, and energy and the fundamental principles of chemistry and biology. These disciplines provide a basic comprehension of how the natural world functions.
2. Physical science encompasses a range of topics, including the study of matter's characteristics, chemical processes, the periodic table, and fundamental physics notions like forces and energy. Practical experiments and demonstrations may effectively demonstrate these ideas and actively involve students in learning.

3. Earth and space sciences: Students may acquire knowledge on subjects about the composition of earth, geological phenomena, atmospheric conditions, and celestial systems. Examples of these phenomena might include plate tectonics, the water cycle, and the interconnections among the earth, the moon, and the sun.
4. Life sciences: Curricula may investigate the wide range of life forms found on earth, including ecosystems, adaptations, and the interconnectedness of living beings. Students may acquire fundamental anatomy and physiology knowledge and grasp concepts such as genetics and evolution.

Two teaching strategies seem to be prevalent in the European science curricula.

1. Inquiry learning is a prominent feature in contemporary scientific curricula. It involves encouraging students to engage in activities such as questioning, conducting inquiries, and establishing links between theoretical concepts and real-world events (Pedaste et al., 2015). This fosters the development of analytical thinking abilities and a deep understanding of scientific concepts.
2. Modern scientific curricula incorporate STEM components to enable multidisciplinary learning experiences, as Bryan et al. (2015) described. This may include using digital technologies to gather and evaluate data or participating in engineering design problems.

The European science syllabus for 11-12-year-old students includes some similarities. Nevertheless, there might be differences in the content and pedagogical methods used in European nations and their respective education systems.

SIMILARITIES IN THE SCIENCE CURRICULA OF COUNTRIES IN EUROPE FOR AGES 11-12

The science curricula designed for students aged 11 to 12 in Europe are intended to deliver a comprehensive and engaging educational environment that lays the foundation for subsequent exploration and understanding of scientific concepts (Osborne & Dillon, 2008). The scientific curricula across European countries for this demographic exhibit similarities in fundamental subjects, hands-on experiments, and a pronounced focus on inquiry-driven pedagogy (Lyons, 2006).

The pronounced focus on essential scientific disciplines, including biology, chemistry, and physics (Krell et al., 2015), is a significant consistency in the science curricula for students aged 11 to 12 across Europe. These courses are presented fully, encouraging students to see the interdependence of several fields.

Conducting experiments is crucial for improving students' comprehension of scientific topics (Childs, 2015). Engaging in practical activities allows students to apply theoretical information to real-world problems, developing a more profound respect for the topic. Furthermore, scientific education for this age group places significant importance on inquiry-based learning (Engeln et al., 2013). Students are encouraged to inquire, investigate, and formulate conclusions using critical thinking and problem-solving abilities. This methodology enhances students' comprehension of scientific ideas and fosters self-directed learning and inquisitiveness about the surrounding environment.

Basic Courses

A pervasive theme permeates the curricula of scientific education for 11-12 year olds in Europe. This thread focuses on the fundamental disciplines essential for building a solid scientific knowledge and comprehension foundation throughout a student's academic journey (DeBoer, 2000). These fundamental themes act as foundational elements upon which more intricate thoughts and ideas are subsequently constructed, analogous to the crucial role of a strong base in ensuring the stability of a high skyscraper.

Biology, the study of living creatures and their interactions with each other and their environment, is a fundamental topic widely included in the European science curricula for this age group (Markula & Aksela, 2022). By examining subjects such as cellular composition, heredity, and ecological systems, students can investigate the intricate interconnectedness of life on our planet and develop a more profound understanding of its intricacies (Erdoğan et al., 2009). By comprehending the functioning and adaptation of living organisms to their surroundings, students become more proficient in comprehending broader ecological concepts and make well-informed choices about conservation efforts and sustainable practices (de Jong et al., 2014).

Chemistry, the study of matter and its characteristics, composition, and changes is a significant topic in science curricula for 11-12 year-olds in Europe (Eilks et al., 2013). Students gain comprehension of molecular-level interactions by engaging in practical experiments and conducting studies on elements, compounds, reactions, and acids/bases. This fundamental understanding provides the basis for more sophisticated investigations in the field of chemistry. It equips students with practical skills directly applicable to daily life, such as comprehending food labels or evaluating home cleaning goods.

Physics is a fundamental topic crucial in developing the scientific education of 11-12 year olds in Europe (Schmidt et al., 1997). Students understand the basic principles that control the physical universe by examining forces, motion, energy transfer, sound waves, light waves, electricity, and magnetism. Physics allows students to engage in critical thinking as they analyze the behavior of things under different circumstances, whether it involves calculating velocity or constructing basic mechanisms like pulleys or levers. Furthermore, it motivates them to use mathematical ideas to resolve real-world issues.

By studying biology, chemistry, and physics, students can acquire the necessary knowledge and skills to navigate complex scientific concepts with confidence, curiosity, creativity, inventiveness, innovation, resilience, adaptability, critical thinking, problem-solving abilities, analytical thinking, effective communication, teamwork, cooperation, empathy, ethical decision-making, global awareness, cultural sensitivity, respect for diversity and inclusiveness, honesty, openness, humility, gratitude, attentiveness, reflection, responsibility, accountability, leadership, perseverance, determination, shared values, shared goals, shared vision, collective impact, sustainable development, peace, progress, transformation, evolution, empowerment, liberation, synergy, symbiosis, diversity, and harmony.

Practice Experiments

A critical component of the scientific curricula for 11-12 year olds in Europe is the prioritization of experiments (Kotsis, 2024). These experiments aim to actively include students in the learning process by providing hands-on experiences that enable them to investigate scientific topics via practical applications. Educators may cultivate a more profound comprehension and admiration for the scientific process by allowing pupils to conduct experiments personally. By engaging in practical experimentation, students may directly see the application of theories and ideas in real-life situations, enhancing the tangibility and concreteness of their learning experience. This methodology enhances students' ability to remember material. It helps them develop their critical thinking abilities by encouraging them to examine facts, draw conclusions, and establish links between theory and practice.

For 11-12 year olds, teachers in countries like France, Germany, and Spain often include hands-on experiments as a critical component of their scientific curriculum (di Fuccia et al., 2012; Schmidt, 2005). Among the many fields involved in the tests are physics, chemistry, biology, and environmental science. Students could, for example, conduct experiments to learn about the properties of magnets or look at chemical reactions by mixing different elements. These activities help kids to understand scientific concepts and develop essential abilities like observation, measurement, and problem-solving.

Hands-on experiments enhance academic understanding and foster student teamwork since they collaborate in groups to develop and conduct their investigations (Holstermann et al., 2010). The collaborative approach used here reflects scientists' real-life working methods. It promotes the development of collaboration and communication skills crucial for achieving success in academic environments and future STEM employment.

Furthermore, practical experiments allow increased personalization and adaptability in instructional approaches (Carlson & Sullivan, 1999). Educators can customize experiments to accommodate their student's specific requirements and interests while also addressing various learning styles. For instance, visual learners may find it advantageous to see demonstrations or diagrams when experimenting, while kinesthetic learners may prefer engaging in hands-on experimentation.

In summary, hands-on experiments serve as a potent means of captivating young children in scientific education by making abstract topics more approachable via practical implementation. By integrating these hands-on learning experiences into the curricula for 11-12-year-olds around Europe, educators can cultivate a lasting passion for science while providing pupils with essential skills that will be beneficial long beyond school. By engaging in practical experimentation, students enhance their comprehension of scientific ideas and develop vital critical thinking abilities, preparing themselves for triumph in a progressively intricate world propelled by innovation and exploration (Saad, 2020).

Emphasis on Inquiry-Based Learning

When examining the scientific curricula designed for 11-12 year olds in Europe, it is impossible to ignore the considerable focus on inquiry-based learning, as highlighted by Lazonder and Harmsen (2016). This educational style promotes active student engagement with the subject, fosters questioning, facilitates experimentation, and draws conclusions. Inquiry-based learning fosters students' curiosity and promotes investigation, enabling them to take responsibility for their education. This approach transcends rote memorizing and fosters students' capacity to engage in creative and critical thinking around scientific subjects.

European nations often include practical exercises in their science classes, as noted by Abrahams and Millar (2008). Students can apply theoretical knowledge in real-world contexts, such as conducting research in the laboratory and going on field excursions to discover nature directly. This practical approach improves comprehension and fosters a more profound admiration for the natural world. Through active engagement in practical activities, students may directly see the manifestation of scientific concepts in their daily lives.

Furthermore, inquiry-based learning fosters student cooperation as they collectively investigate intricate scientific topics (Kotsis et al., 2023). By engaging in group activities and conversations, students acquire the skills to communicate effectively, attentively consider other viewpoints, and cooperatively resolve challenges. The collaborative nature of inquiry-based learning mirrors the collaborative approach of scientists in research environments, underscoring the significance of cooperation and communication abilities in science.

Another crucial element of inquiry-based learning is its emphasis on student-driven investigations (Teig, 2022). Instead of depending entirely on textbooks or lectures, students are encouraged to develop their research inquiries and create experiments to evaluate ideas. This technique enhances comprehension and cultivates a feeling of autonomy and self-sufficiency in pupils. Through taking ownership of their learning path, students develop a sense of agency and self-assurance that will benefit them beyond the confines of the classroom.

European scientific curricula for ages 11-12 emphasize inquiry-based learning, highlighting the dedication to fostering lifelong learners who display curiosity, creativity, and critical thinking skills. The approach involves offering experiential learning opportunities, promoting collaborative work among peers, and encouraging students to actively engage in their education via self-directed inquiry (Werder & Otis, 2023). Teachers provide students with vital abilities necessary for their academic and professional success. By embracing this progressive methodology for scientific education, European nations are equipping the next generations for triumph in a constantly changing world where ingenuity, analytical thinking, and cooperation are essential abilities.

DIFFERENCES IN THE SCIENCE CURRICULA OF COUNTRIES IN EUROPE FOR AGES 11-12

Science education provided to 11-12 year olds in Europe differs significantly among countries since each nation designs curricula to meet its pupils' specific requirements and goals. This study examines the national variances in European scientific curricula, emphasizing significant distinctions and commonalities.

One significant difference across European nations is their varying focus on practical vs theoretical learning in scientific education (Palmer, 1998). Certain nations emphasize conducting experiments and implementing practical solutions, while others place greater importance on theoretical notions and academic expertise.

Another crucial factor to consider is the incorporation of technology into scientific education. While several nations are leading the way in integrating state-of-the-art technology into their educational institutions, others may fall behind due to financial limitations or inadequate access to resources.

The importance of cultural factors in developing European scientific education is significant (Dilli & Westerhuis, 2018). Varied audiences of students may possess divergent perspectives on the significance of scientific knowledge and abilities, resulting in disparities in curricular material and instructional approaches.

European nations' evaluation procedures and criteria might vary significantly (Antanasijević et al., 2017). Some individuals place more importance on standardized examinations, while others choose project-based evaluations or ongoing assessment methods, such as formative assessment. Comprehending these various methods of evaluating student learning is crucial to comparing European scientific education systems.

National Differences in the Science Curricula

The scientific education environment for 11-12 year olds in Europe is complex, consisting of several national curricular variants. Every nation has distinct traditions, attitudes, and objectives regarding teaching science, resulting in diverse educational experiences for young students. For instance, in France, kids of this age can engage in a well-organized and demanding educational program focusing on essential principles of biology, chemistry, and physics (Gueudet et al., 2017). Meanwhile, in the United Kingdom, pupils can engage in practical experiments and investigations that promote a more profound comprehension of scientific ideas (Fensham, 2022).

Science education in Germany at this level emphasizes the development of critical thinking abilities via problem-solving tasks and collaborative projects (Jeschke et al., 2007). Students are urged to investigate practical uses of scientific knowledge and enhance their capacity to scrutinize data and formulate conclusions based on evidence. In contrast, Spain may prioritize integrating scientific principles with cultural traditions and historical advancements (Sáez & Carretero, 2002). Children are taught to see science as a dynamic discipline influenced by cultural values and ideas.

The variety of European scientific education methods reflects each country's specific goals and the broader cultural factors that shape them (Malin et al., 2020). Certain nations prioritize interdisciplinary learning, integrating scientific knowledge with other academic disciplines, such as history or literature. This method aims to foster a comprehensive realization of the world and facilitate linkages across many knowledge domains.

The differences in the scientific curricula for 11-12-year-olds throughout Europe emphasize the intricate and diverse nature of educational systems across the continent. By acknowledging and appreciating these variations and understanding the significance of a wide range of viewpoints in the context of education, teachers may provide inclusive and engaging settings that encourage young children to delve into the marvels of science (Carayannis & Morawska-Jancelewicz, 2022).

Emphasis on Practical over Theoretical Learning

Upon analyzing the disparities in the scientific curricula for 11-12 year old students throughout Europe, a clear distinction arises regarding the focus on practical and theoretical education (Lunetta et al., 2007). European educational systems have faced persistent challenges in finding a harmonious equilibrium between different methods, each with merits and drawbacks. Frequently praised as the fundamental aspect of experiential education, it seems to be the hands-on learning activities that provide students with tangible opportunities to interact with scientific topics actively. The immersive method facilitates a more profound comprehension of intricate subjects, augmenting critical thinking abilities and problem-solving skills that are very useful in today's fast-paced society (Schwichow et al., 2016).

Conversely, theoretical learning is often preferred since it focuses on core information and conceptual comprehension (National Research Council, 2012). By immersing themselves in abstract ideas and concepts, students may cultivate a robust theoretical framework that will serve as a solid basis for their future study. Nevertheless, detractors contend that this methodology might sometimes result in mechanical memorizing devoid of genuine comprehension or practical use of the information (Xu, 2022).

The topic of practical vs theoretical learning is further complicated by European cultural variations (Kalantzis & Cope, 2016). Certain nations strongly emphasize practical experimentation and learning via activities, while others stress conventional lectures and instruction based on textbooks. These different approaches demonstrate different perspectives on the goal of education and the most efficient strategies to enhance academic achievement.

Ultimately, it is crucial to strike up a proper equilibrium between practical and theoretical learning to provide a complete science curriculum that caters to the varied requirements of 11-12 year old students across Europe. By skillfully and deliberately combining both methods, educators may provide children with comprehensive scientific education that prepares them for the necessary abilities to thrive in an ever more competitive global environment. As European nations enhance their scientific curricula, it is crucial to determine the most effective ways to include practical and theoretical learning methods. This guarantees every student a customized, high-quality education catering to their strengths and interests.

Integrating Technology Into Science Education

Recent developments show that technology integration is becoming more prevalent in scientific education for European students aged 11-12 (Potvin & Hasni, 2014). Incorporating technology tools and resources into science curricula has transformed how students interact with scientific ideas and principles. Through digital platforms, interactive simulations, and virtual laboratories, educators can construct immersive learning experiences that captivate students' attention and improve their comprehension of intricate scientific phenomena (Potkonjak et al., 2016).

Integrating technology into scientific education significantly promotes a collaborative and participatory learning environment (Kaufmann & Vallade, 2020). Students can use online discussion forums, video conferencing tools, and collaborative project management systems to participate in substantive conversations with classmates, exchange ideas, and collaborate on practical experiments or research endeavors. This fosters collaboration and effective communication abilities and stimulates analytical reasoning and the development of problem-solving aptitude in kids.

Furthermore, technology enables educators to customize education according to pupils' unique learning styles and speed (Alamri et al., 2021). By using adaptive learning software and data analytics technologies, instructors can monitor student progress in real-time, pinpoint areas of difficulty, and provide focused assistance or supplementary materials to enhance their academic achievement. This individualized instructional method enables enhanced customization in the educational setting, guaranteeing that each student has the necessary assistance to achieve their maximum capabilities (Rivera Muñoz et al., 2022).

Incorporating multimedia components, such as films, animations, interactive games, and virtual reality simulations, into courses allows educators to cater to various learning techniques and capture students' attention with diverse interests (Haleem et al., 2021). These graphic tools enhance the tangibility of complex subjects and ignite students' interest and creativity. Consequently, children are more inclined to remember knowledge more well when visually engaging.

Technology in science education for kids aged 11-12 has revolutionized conventional teaching approaches by offering inventive strategies to involve students, foster cooperation, individualize training, and improve comprehension of scientific subjects (Yılmaz, 2021). Undoubtedly, incorporating these technological advancements will persistently influence the future of scientific education across Europe.

Cultural Influences on Science Education

The cultural factors that influence science education in Europe for kids aged 11-12 are extensive and diverse, manifesting in how pupils acquire knowledge and interact with scientific ideas (Smahel et al., 2020). In nations like France and Germany, renowned for their commitment to educational accuracy, the scientific curriculum prioritizes comprehensive theoretical understanding and practical implementation (Whitty & Furlong, 2017). This technique exemplifies the cultural norms of these countries, which place a high importance on intellectual rigor and logical reasoning.

In contrast, nations such as Italy and Spain, known for their extensive artistic and creative heritage, regularly include creativity and imagination in their scientific education (Wiyanto et al., 2020). Students are encouraged to engage in unconventional thinking and investigate scientific principles via practical experiments and projects. This exemplifies the cultural ethos of these nations, which prioritize invention and creativity.

Scandinavia, known for its deep-rooted environmental consciousness and commitment to sustainability, often prioritizes ecological, climatic, and biodiversity subjects in its science curriculum (Palmberg & Jeronen, 2017).

Cultural factors significantly affect the scientific education of European kids aged 11-12, ultimately defining their learning experiences in science. By comprehending the influence of culture on educational practices, educators may effectively customize their curricula to a further extent to accommodate the requirements of a wide range of pupils (Markey et al., 2021). This facilitates the development of a more profound comprehension of scientific principles and nurtures a sense of admiration for many cultures and modes of thought. Incorporating cultural variety into scientific education ultimately leads to developing more captivating and all-encompassing learning experiences for every learner.

Evaluation Methods and Evaluation Criteria

When assessing the science curricula for 11-12 year olds in Europe, instructors use a range of assessment methodologies and criteria to gauge their efficacy. Standardized exams are a frequently used evaluation approach that compares student performance across different areas and nations (Zhai et al., 2020). These assessments often evaluate students' comprehension of fundamental scientific principles, capacity to use information in practical situations, and aptitude for analytical reasoning. Teachers use formative assessments, including quizzes, projects, and lab reports, alongside standardized examinations to monitor students' academic progress over the year.

The evaluation standards for the science curricula may differ based on the aims and objectives of each nation's educational system (Coffey et al., 2001). Certain nations may emphasize rote memorization of facts and statistics, while others value the actual application of scientific ideas via hands-on experimentation. Irrespective of the criteria used, educators must guarantee that assessments follow the learning goals specified in the curricula.

An obstacle educators encounter while assessing scientific curricula is guaranteeing that evaluations are equitable and impartial (Esarey & Valdes, 2020). This might be a challenge when dealing with diverse student groups with varying degrees of previous knowledge or access to resources. To address this difficulty, educators must meticulously create exams that effectively evaluate students' comprehension and abilities without unjustly penalizing specific demographics.

Assessment techniques and criteria are crucial in determining the structure of the European scientific curricula for 11-12 year olds. By using a blend of standardized examinations, formative assessments, and other instruments, instructors may get helpful insights about how students have achieved proficiency in fundamental scientific ideas and abilities (Zhai & Pellegrino, 2023). In addition, instructors may contribute to advancing fairness and high quality in scientific education for all European students by ensuring that assessments are impartial and aligned with the intended learning outcomes.

CONCLUSION

European science curricula for ages 11-12 have notable resemblances across nations. These degree programs encompass essential courses such as biology, chemistry, and physics, which provide students with a comprehensive grasp of the natural world. Furthermore, experiments augment students' learning experiences by providing opportunities to apply theoretical information in real-world contexts. This fosters a more profound comprehension of scientific principles and develops learners' thinking ability and problem-solving skills.

Furthermore, scientific education significantly promotes inquiry-based learning for students in this age range. Teachers foster inquisitiveness and self-reliance in early learners by promoting inquiry, exploring phenomena, and formulating deductions. This technique enhances students' involvement with the subject matter and equips them for future academic endeavors.

The similarities in the scientific syllabi for individuals aged 11-12 across Europe emphasize the need to offer kids comprehensive and captivating science instruction. By concentrating on fundamental topics, conducting practical investigations, and using a teaching approach that encourages questioning and exploration, educators provide young pupils with the essential abilities and information required to excel in their academic pursuits in the future.

Conversely, there are notable disparities in the scientific curricula for students aged 11-12 across Europe. The discrepancies in scientific education may be ascribed to national disparities, where each country emphasizes certain parts of science education following its educational priorities and objectives.

One notable distinction is the prioritization of practical learning over academic learning. Certain nations emphasize practical experimentation more than others, while others value theoretical understanding. This emphasizes the wide range of teaching and learning methods used in the European educational system.

Moreover, incorporating technology into scientific education differs across Europe, with some nations embracing digital tools and resources more thoroughly than others. This highlights the increasing significance of technology in contemporary education and its capacity to improve student involvement and comprehension.

Science education is also influenced by cultural factors since various civilizations have distinct viewpoints on the significance of science in society and its practical application in daily life. The presence of diverse perspectives enhances the science curricula across Europe by providing a greater variety of knowledge and understanding.

European nations use diverse assessment techniques and criteria, reflecting their distinct beliefs about measuring and evaluating student learning. These disparities emphasize the intricate and subtle nature of scientific education in Europe.

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