

**160 YEARS AFTER THE ORIGINS: WHAT IS NEEDED TO PROMOTE EVOLUTION
LITERACY IN EUROPE**

**160 ANOS APÓS AS ORIGENS: O QUE É NECESSÁRIO PARA PROMOVER A LITERACIA
EVOLUTIVA NA EUROPA**

**160 AÑOS DESPUÉS DE LOS ORÍGENES: ¿QUÉ SE NECESITA PARA PROMOVER LA
ALFABETIZACIÓN EVOLUTIVA EN EUROPA?**

**Charis-Marina Antonatou¹, Bento Cavadas², Maria João Fonseca³, Evangelia Mavrikaki⁴, João
Silva⁵ & Xana Sá Pinto⁶**

¹Faculty of Primary Education National & Kapodistrian University of Athens, Greece
charisanton@gmail.com

²Polytechnic University of Santarém, School of Education; Lusófona University, CeIED - Interdisciplinary
Research Centre for Education and Development, Portugal
bento.cavadas@ese.ipsantarem.pt

³Natural History and Science Museum of the University of Porto, Portugal
mjfonseca@mhnc.up.pt

⁴Department of Pedagogy and Primary Education National & Kapodistrian University of Athens, Greece
emavrikaki@primedu.uoa.gr

⁵CJD International School, Portugal
joao.silva@colegiojuliodinis.pt

⁶Research Centre in the Didactics and Technology in the Education of Trainers (CIDTFF.UA), Department
of Education and Psychology, University of Aveiro, Portugal
xanasapinto@gmail.com

ABSTRACT | This paper reflects on insights from two teachers' educators, a science museum head of communication, one elementary school teacher from Portugal and one secondary school teachers from Greece, prompted by the study "Evolution in European and Israeli school curricula - A comparative analysis." Emphasizing the paper's significance in guiding curriculum revisions, the participants advocate for collaborative efforts among science education researchers, evolutionary biologists, teachers' educators, and educators to align research with curriculum and teaching practices. They stress the importance of creating educational materials and teacher education programs that empower educators to address education for sustainability through an evolutionary lens from early school years. Furthermore, they underscore the necessity for additional research on integrating evolution into elementary education, aligning learning objectives across grades, evaluating educational resources, and engaging with religious students on evolutionary topics.

KEYWORDS: Evolutionary literacy, Curriculum analysis, Teacher training, Educational resources, Elementary schools.

RESUMO | Este artigo reporta as reflexões de dois formadores de professores, da diretora de comunicação de um museu de ciência, de um professor do ensino primário em Portugal e um do ensino secundário na Grécia, inspiradas pelo artigo “Evolution in European and Israeli school curricula - A comparative analysis”. Enfatizando a importância do artigo na orientação de revisões curriculares, os participantes defendem a necessidade de esforços colaborativos entre investigadores das ciências da educação, biólogos evolutivos, formadores de professores e educadores, para alinhar os currículos e práticas de ensino com a investigação. Destacam a importância de desenvolver recursos educativos e programas de formação de professores que capacitem os educadores para abordar a educação para a sustentabilidade através de uma perspectiva evolutiva, desde os primeiros anos escolares. Salientam ainda a necessidade de mais investigação focada na introdução da evolução desde os primeiros ciclos de ensino, no desenvolvimento e avaliação de recursos educativos e em estratégias para abordar a evolução com estudantes religiosos.

PALAVRAS-CHAVE: Literacia evolutiva, Análise de currículos, Formação de professores, Recursos educativos, Escolas primárias.

RESUMEN | Este artículo reflexiona sobre las ideas de dos formadores de profesores, un responsable de comunicación de un museo de ciencias, un profesor de primaria portugués y un profesor de secundaria griego, motivados por el estudio “Evolution in European and Israeli school curricula - A comparative analysis”. Enfatizando la importancia del artículo en las revisiones curriculares, abogan por esfuerzos colaborativos entre investigadores en educación científica, biólogos evolutivos, formadores de profesores y educadores para alinear la investigación con el currículo y las prácticas de enseñanza. Destacan la importancia de crear materiales educativos y programas de formación de profesores que los capaciten para abordar la educación para la sostenibilidad de una lente evolutiva desde los primeros años escolares. Subrayan la necesidad de investigaciones sobre la integración de la evolución en la educación primaria, alineando los objetivos de aprendizaje en todos los grados, desarrollando recursos educativos y relacionándose con estudiantes religiosos sobre evolución.

PALABRAS CLAVE: Alfabetización evolutiva, Análisis curricular, Formación docente, Recursos educativos, Educación primaria.

1. INTRODUCTION

When we celebrate 160 years since the publication of Darwin's most famous book (On the origin of species by means of natural selection; Darwin, 1859) several studies show that evolution is still not understood by many people across the world (Kuschmierz, 2022; Cavadas & Sá-Pinto, 2023) despite its central importance to understand natural world and address important sustainability changes (Jørgensen et al., 2019; Kampourakis, 2022). To understand how national curricula are contributing to promoting public literacy in evolution, 45 authors, including science education researchers, science teachers and evolutionary biologists, all members of the EuroCitizen COST Action (<https://www.euroscitizen.eu/>) analysed 19 school curricula (18 European countries and Israel's). From this collective effort resulted the paper "Evolution in European and Israeli school curricula - A comparative analysis" (Mavrikaki et al., 2024) that analysed the official documents guiding education until the 9th-10th grade, the end of the shared curricula in most countries. The study aimed to uncover the minimum education a person could receive relative to evolution in each of these countries. The findings of this paper are worrying us as they show that (i) less than half of the essential learning goals for scientific literacy in evolution are included in the curricula; (ii) prevalent learning objectives focus on very basic evolutionary knowledge; (iii) goals pertaining to the mechanisms of evolution are frequently omitted or inadequately covered; (iv) connections between evolution and its real-world applications are often absent. The present round table aimed to discuss the results of this paper and what is needed to further strengthen public evolution literacy. The round table took place on the 7th of March 2024 and lasted approximately 60 minutes. Five people participated in the round table.

Evangelia Mavrikaki is the first author of the paper. She is a biologist and a Professor at the National and Kapodistrian University of Athens, Greece, in the Department of Pedagogy and Primary Education where she teaches biology education and health education to future teachers. She has been president of EvoKE and the co-leader of the Formal Education working group of the EuroCitizen COST Action. This working group aimed to understand how formal education could better contribute to fostering public literacy in evolution.

Bento Cavadas is also author of the paper and a science education teacher at the Polytechnic Institute of Santarém, Portugal, where he prepares his students to become science and mathematics teachers. He was a member of EuroCitizen COST Action and his research interests include to understand pre-service teachers' conceptions about evolution and how to better prepare them to mobilise their evolution knowledge and skills in their future classes in kindergarten and primary school.

Charis-Marina Antonatou holds a degree in biology and serves as a secondary school teacher at the High School of Koroni, located in Messinia, where she teaches biology to her students. She is currently pursuing her doctoral studies, exploring secondary school teachers' knowledge of the nature of science and how this knowledge affects their understanding and acceptance of evolution.

João Silva is a primary school teacher. He is now teaching at an International School in Portugal that follows the Cambridge curriculum but he has prior experience as a primary school teacher both in Portuguese schools based in Portugal and in English schools based in the UK.

Maria João Fonseca is the head of communication of the Natural History and Science Museum of the University of Porto and the director of the Hall of Biodiversity science centre. She

is also a researcher on science education and communication, and her research has been mostly focusing on the assessment of the impact of educational activities.

Evangelia and Bento, can you briefly explain what were the motivations of this paper and its main results and what are its main implications for education policies, practices and teacher training?

Evangelia: What motivated this research was the large evidence coming from the literature supporting that, in many countries, people do not understand or accept evolution. So, we wondered what could be the role of school curricula in this problem. What have these people been taught in their schools about evolution? Is evolution taught similarly across Europe or does evolution education vary across countries? Is evolution taught to all European students or only to those who will follow scientific careers?

To answer these questions, we decided to analyse the curricula from the 1st to the 9th grade, which are the grades during which, in most countries, students follow the same disciplines and the same curricula. In some countries, we further extended the analysis up to the 10th grade or 11th as curricula is shared until then. This choice of grades also allowed us to focus on students who, in many countries, will complete compulsory education and are approximately 15 years old which is also the age at which PISA evaluation is performed. We decided to focus on the biology curricula. When there was not a biology subject, we analysed the natural science subjects where biology was included.

We performed a quantitative content analysis of the learning goals in each curriculum to find out which evolution key ideas were present. For that we used FACE, a framework of analysis that we have developed in a previous article by almost the same authors. This framework is useful for analysing curricula and developing educational material, as it provides the key ideas needed to develop literacy in evolution focusing on 6 major dimensions: history of life, evidence for evolution, mechanisms of evolution, studying evolution, nature of science and scientific practices. These dimensions are needed to promote evolution understanding but also its acceptance.

The results we obtained revealed that, in the analysed countries, the curricula that apply to all students include less than half of the key ideas needed to promote evolution literacy. Also, very important, our results show that the analysed curricula give little to no importance to the processes that drive evolution and do not explore daily life examples of evolution. I think that the patterns we found may explain, at least partially, why so many people in Europe and worldwide outside Europe do not understand or accept evolution and I think that more research is needed to test this hypothesis.

Regarding the impact of our results I think these should be considered by the people who design educational policy and that it is important to redesign the curricula considering our results and addressing the identified problems. But our results are also important to rethink and redesign teacher training. In fact, we can train teachers to overcome the problems we identified and explore the learning goals that are missing in the curricula. As evolution is transversal and central in biology, teachers can easily address the missing evolution learning goals in their everyday teaching practices, even if these are not explicitly mentioned in the curriculum.

Bento: In my opinion the paper has many implications for educational policies, practices and teacher education, which is my work field. Evolution is closely related to critical thinking and if we want to promote the development of this competence in students, then the curricula should include the necessary learning goals to promote evolution literacy that could be addressed both in formal and non-formal education contexts. Moreover, evolution understanding is closely related with health literacy for example. I think that COVID19 pandemics could have been better understood by the general population and by future teachers if they possessed a deeper understanding of evolution and evolutionary mechanisms. These are some of the reasons why it is so important to overcome the problems we identified in the curricula in the paper published in 2024.

What collaborations between researchers, educators and teacher trainers do you feel are needed to promote educational practices that effectively overcome the problems that were identified in the paper?

Charis: This paper illustrates the significant differences in the content and depth of evolution education in different countries. Reflecting on my experience within Greek schools, it appears that teachers lack confidence in teaching evolution. This insecurity leads them to rely solely on textbook material. To address this issue, it is crucial to prioritise the empowerment of teachers in teaching evolution. By enhancing their knowledge and confidence, teachers can navigate the shortcomings identified in existing curricula, even if changes in school curricula take time to implement. While the process of curriculum revision may pose challenges, it is essential to seize opportunities to improve the incorporation of evolution and its characteristics into educational materials. Although long awaited changes in Greek textbooks are anticipated the following year, the specifics remain uncertain, leaving questions about potential enhancements in the coverage of evolution unanswered.

João: Regarding this question, I agree with Charis. I feel that collaborations between researchers, teachers and teachers' trainers are crucial to address the challenge and fight the problems in evolution learning goals found in the various curricular dimensions analysed in this paper. For example, it is much easier for a researcher to identify and make evolution visible in topics where evolution is not explicitly mentioned. This would allow us to explore evolution in different subjects, even for example in Portuguese language curriculum as languages also evolve. Another example is vaccines and vaccination. For teachers, identifying these issues while working is a difficult task and this is a problem that can be easily overcome through collaboration with researchers. So, I find that these collaborations could really contribute towards that goal.

Maria João: Well, we at the Natural History and Science Museum of the University of Porto do collaborate a lot with researchers. Some museums do have researchers in their boards, and sometimes they are the ones in charge of engaging in educational activities. And it's true what João said. I feel that it's true that researchers, especially evolutionary biologists, do have a wider view on topics that can be addressed even though they may not have the tools to develop educational activities, and this highlights the importance of the partnerships between these, science education researchers and teachers. The challenge is knowing how to better support

these collaborations. We have been thinking about providing and updating teacher courses for in-service teachers, for instance and inviting researchers working on different topics of evolution to engage with teachers and educators, to create educational activities that can then be put in place in schools or at the museum. But so far, we have not yet implemented this idea.

Sometimes we do have researchers working on specific fields - evolution included - talking to teachers, and the content of the course may be extremely relevant. But my experience suggests that, often, teachers do not profit from those, because they feel that, even though these courses contribute to their understanding of a topic that is included in the curricula, these do not necessarily fit what they do have to address in their classes. So, the idea would be to mediate the knowledge that researchers have on these specific topics and adjust the way in which these are worked through, to meet what teachers and educators need for their own teaching practice when dealing with students, children, or adults. So, I agree that collaboration is fundamental. My question is how can we promote it in an effective way.

Evangelia: Something we also learned during the research we carried out in this paper is that, in different countries, teachers have different degrees of freedom. That is why some of the curricula we analysed were short and with fewer guidelines while others were much more extensive with lots of guidelines and proposed activities for students. We definitely have to take these different degrees of teachers' freedom under consideration, not only when thinking about schools but also when thinking about teachers' education as this will affect their ability to further explore evolution during students' education, despite the curriculum. Finland's curriculum, for example, didn't have so many guidelines for teachers and their teachers have more freedom when applying the curriculum, if I remember correctly. But Finnish teachers are highly trained to do that: both at their pre-service training but also through a strong in-service training program all along their careers.

I feel science museums and other non-formal education institutions can greatly contribute to teachers' in-service training. Of course, it is also important that researchers from natural sciences and from science education in informal and formal contexts collaborate to develop new curricula. But for me, what is the most important thing, is that they collaborate to train teachers. Training teachers to empower them to teach about evolution will always be needed and fundamental, even when evolution is well represented in the curricula. But when the curriculum does not include some important goals, a trained teacher can include these in his/her everyday practice. We should account for the hidden curriculum, not only the formal curriculum. I mean, what the teachers choose to teach deeper or shallower is also very important. And teacher training would greatly benefit from the collaboration between researchers and teachers.

Bento: I want to stress some ideas that Maria João and Evangelia have just expressed, because I really agree that we must have in-service teacher education programs on evolution with collaboration of researchers. This is very important to maintain evolution on teachers' focus. We must be aware that teachers are asked to give attention to many different topics and if we do not provide them opportunities to participate in evolution education workshops or other forms of training, there is a risk of teachers neglecting evolution education.

But I also think that, if we want to address the importance and relevance of evolution education, we must integrate it into the official curriculum with further detail. The reason is that if evolution is included in the official curriculum, it will also be incorporated into textbooks, which, in my opinion, will further facilitate the integration of evolution education into classrooms.

Maybe I am a little bit enthusiastic about it, but in my opinion, we should have evolution education from kindergarten and primary schools, because there we can find the basis for the scientific reasoning and for the understanding of the evolution major concepts. So, the idea would be to mediate the knowledge that researchers have on these specific topics and adjust the way in which these are worked through, to meet what teachers and educators need for their own teaching practice when dealing with students, children, or adults about the nature of science. In my opinion, it is crucial to include the fundamentals of evolution education since kindergarten and primary school curricula.

João: I would like to say that I completely agree with the Bento. There, has to be a restructuring of the curricula coming from above. We cannot just rely on teachers to do the connections between evolution and the science topics as this is not what they were trained for.

I have to mention that, after reading the paper I went to examine both student books in the Cambridge curriculum and it's evident that evolution isn't explicitly addressed and it's also not addressed in the Portuguese books, at least in the 5th and 6th grade. However, there are subtle indications about how organisms utilize resources and about processes that ensure survival and propagation of the species.

But while the content is logical and logically presented, direct connections to evolution and its sub categories are lacking. Extending the contents to further integrate great evolutionary concepts depends on each teachers' discretion, and it's not compulsory. Yet relying only on the teachers' initiative isn't ideal, as it leaves the incorporation of evolutionary principles to their discretion, potentially leading to inconsistencies in students' understanding of biological processes. So, I completely agree this has to come from the curriculum, otherwise I don't think this is going to be addressed by all nor even by the majority of the teachers.

Charis: I strongly agree. In Greece, evolution is not a mandatory component of the education curriculum, leaving only a minority of students exposed to its contents. Even among those who do encounter it, the treatment of evolution tends to be cursory, often presented at the end of textbooks with limited attention from teachers, instead of acknowledging it as the unifying theory of Biology. Consequently, only a select few students receive a superficial understanding of key evolution concepts. Given these circumstances, I strongly advocate for the introduction of evolution education at an earlier stage. By integrating it into the curriculum from a younger age, we can ensure that a broader spectrum of students is equipped with a foundational understanding of this fundamental scientific theory.

How can science education research contribute to educational practices in evolution that ensure that all learners acquire the knowledge and skills needed to promote sustainable development?

Evangelia: In my opinion, education research, is a very promising way to achieve whatever we want to see applied in schools. We provide the evidence for those who design the policy. At least it should be like that. But unfortunately, it's not always like that. In Greece, for example, this is not the case. Unfortunately, many important findings from science education research are never taken under consideration. For political reasons, many of these research findings are never applied in education. However, this should be the driving motor of any education reform. I mean when designing curricula, the results of research in education should be applied and used to inform practices in schools. This is however done in primary or secondary education departments in universities, and there should be this connection between universities, research in education and the university educational policy.

Regarding the sustainability goals, I don't think there is such a huge gap between science and humanities and evolution is a very good example of that. In my opinion people who understand and accept evolution, understand why there are and there should be diversity in life and these people cannot be so easily influenced by racists. They can understand that there are no such things as human races and that “pure races” are not good for species'/populations' long-term evolution and adaptation. So, I think that understanding and accepting evolution can promote humanistic values.

Bento: When you asked that question I immediately thought about biodiversity and educational practices about biodiversity. In fact, I do many activities related to biodiversity because I think students must understand that all living beings are interconnected and depend on each other. And this also applies to humans: we are different, but we are also interconnected and depend on each other. I think this idea of the evolution of life can and should be mobilized to explore topics such as human biological and cultural diversity, global citizenship, among others.

Studying evolution can also promote critical thinking skills as students are asked, for example, to analyse evidence and argue using logical arguments. These skills are essential for addressing complex societal challenges such as climate change or artificial intelligence, among other issues, promoting a culture of evidence-based decision making. This is very important in this period where fake news and fake science are proliferating and spreading. We have much to accomplish regarding evolution education and the promotion of sustainable development goals. However, evolution and its principles offer a robust foundation for addressing sustainability challenges.

Maria João: I was listening to Evangelia and Bento and I completely agree. Something that we, at the Hall of Biodiversity, always work through whenever addressing biodiversity, is that there's no biological basis for discrimination among humans as we are all very diverse. So many humanistic values can indeed be addressed through biology education and specifically biodiversity education. And I also agree that evolution education allows us to become more

critical on the way we assess information and on the relationship between contents, events and phenomena.

Research on science education and evolution education, in particular, is of key relevance to have teachers develop educational practices on evolution. Again, examples like this paper in particular and sharing practices that are aligned with the science education curricula, but specifically address contents related to evolution and to biodiversity that are of use to their practice.

I would like to stress the fact that we, as teacher trainers, do have to focus on what's relevant for teachers to engage in. Obviously, we need to open new horizons and share information that is relevant and that may be state-of-the-art, but still, we do need to make connections to their needs and to the real-life contents they need to work through with their students. And if we manage to get natural sciences' researchers and educational sciences researchers to come together to show how this can be done, it would be very efficient. I'm not entirely sure how to do it, but I feel this would be very efficient because we would be able to provide educators, teachers and teacher trainers with examples of how to connect both content and practice to allow their students - adults and children alike- to achieve the expected learning goals.

Charis: I agree with the views expressed by all of you. I was thinking of how we can leverage the flexibility within our school system to incorporate problem-based exercises or fieldwork into our teaching approach. We are situated in the rural area of Messinia and so, we have the opportunity to venture outdoors, facilitating hands-on discussions that enhance students' comprehension of topics such as climate change and biodiversity, as Bento aptly highlighted.

Collaborations with researchers present a valuable avenue for enriching our teaching practices. In my opinion, we can overcome the problems with evolution education if educators can effectively integrate real-world applications of evolutionary concepts into their lessons. I firmly believe that, by contextualising evolution within everyday life, we can bridge the gap in understanding and concurrently contribute to achieving our learning goals.

João: I was hearing your answers to this question and talking about diversity and how we can improve the relations among people from different cultures and people with different features and I immediately thought about the first days of school. Especially in an international school where we have different students, coming from different parts of the world, and some coming from places where they are used to seeing people with similar features, so they are obviously curious about diversity. In the first few days, with this lack of experience from some students with human diversity, some issues arise and I have to bring up the subject of evolution to explain basic concepts. I'm not an expert on evolution, but I had to explore evolution to explain basic concepts in order for them to understand human diversity. And this has to do with evolution and with human adaptation. All in all, we are all people with just different characteristics and that basically happened because of evolution.

So, evolution can help students to better understand human diversity and this is important as they will eventually grow up to become adults and voters. So, I think this is a crucial topic to explore in schools.

If you were allowed to set the agenda for education research for the next, let's say, three years, what do you think would be the most important directions to follow in education research?

Evangelia: I would go with researching the teaching of evolution from the very first grades because we already have research regarding what older students and adults know and understand about evolution and about what and how evolution is taught in schools from higher grades. We also do have some research regarding what teachers know and about evolution and whether they accept it or not in some countries. So, I feel the next step should be to research about teaching evolution from the very, very first grade, from kindergarten: how we could introduce evolution in these grades, what would be the best way to do this and how we could train elementary school teachers to do this. It would also be important to do some research about how we can develop relevant educational material to support teachers. A well-developed educational material would help teachers to promote students' learning about evolution. This is, in my opinion, what we should focus on.

Bento: I agree with Evangelia's suggestions. I would like to stress her last idea about the importance of educational resources. In my opinion, research should facilitate our understanding about the most effective educational resources to teach evolution. What are the features and main characteristics of these resources? This is very important because, in my experience, teachers are always looking for the best educational resources to deliver the curricula content. If we identify, create and share effective resources in a way that teachers can easily find, download and adapt them, for sure teachers are going to use these.

Maria João: I would like to reinforce what both Evangelia and Bento said. When preparing a research agenda, we should make sure that it focuses, longitudinally, in various ages and school years, starting from an early basis onwards. At least in our country, as you know, whenever we try to enact changes in the curricula, sometimes these do not seem to work. But because we do not implement these measures longitudinally and consistently, across the various school years, we lose the ability to understand why they fail. So, introducing change from an early age, and letting it carry on along the next school years, would make sense. Also, I do agree that it would be relevant and useful to identify good practices, collecting some indicators on what works better and conveying all that information in a single access point. It would be important to have educational resources validated to reassure practitioners that these are relevant and effective for their practice. These two aspects I think would be of great value when thinking of preparing an agenda.

João: Well, in practice I think we need to place more emphasis on the subject of science so that this is not just a secondary subject. Disciplines such as languages and mathematics are perceived as the main subjects and science is usually the extra sibling in school curricula. This happens because, of course, we have more final exams for mathematics and language disciplines than for science. Parents are usually more concerned with these two subjects and pay less

attention to science because, at the end of the day, they will have an exam on language or mathematics subjects and not science.

There's also another issue in the Portuguese schools. When I started reading this paper and thought of my previous work as a Portuguese school teacher and how it was so difficult sometimes to address the topic of evolution. This is not so strong in the international school where I work now. But several times I had to make sure my students understood me when I was answering questions about evolution and other science topics that I was addressing those under a scientific perspective and not under a religious perspective. Their interventions regarding any science subject many times were to questioning as they felt scientific explanations were conflicting with the religious views that they were exposed to in their religious studies at the church. It would be much easier to just dismiss these interventions and, say, science is science and religion is religion; we don't talk about religion in science classes. However, we have two factors: on one hand we have the parents and I'm sure that some of them would challenge my statements, even though religion does not play any part in the science curriculum; on the other hand, it is challenging to say to the vast majority of children that in science we deal with empirical evidence and knowledge. So, to conclude this thought, the environment in which children are brought strongly affects how we can approach a subject. So, I think it is also important to do research on how to approach evolution to an already biased audience. Luckily, we are dealing with children and I like teaching children because they allow themselves to think and change their own minds if needed.

Charis: I believe there's a discrepancy in how science is represented in the earlier grades of Greek schools, perhaps due to the inclusion of religious studies from a young age. That could lead to misconceptions which may persist and accumulate as students progress through the education system. Therefore, I support the notion of introducing evolution at an earlier stage in the curriculum.

I fully endorse Bento's emphasis on the necessity for teachers to be equipped with effective tools, particularly in tackling complex topics such as evolution. Also, Maria João's point regarding the importance of coherence across grades is well-founded. A more seamless integration of topics across curriculum, spanning from kindergarten to secondary school, is essential. Currently, in Greece, there is a disparity concerning the timing of the curriculum revisions, with significant changes occurring only at specific junctures, such as in gymnasium and lyceum (9th and 12th grades, respectively). This disjointed approach creates discontinuity and creates obstacles in developing a cohesive educational framework.

CONCLUDING REMARKS

The round table discussion emphasizes the need to integrate key evolution concepts into curricula from early school years to the end of the shared curricula. These changes should be mirrored in textbooks. Additionally, there is a crucial emphasis on empowering teachers through effective training programs to teach evolution across all grades, aligning with daily contexts and sustainability problems. Collaboration among educators, trainers, biologists, and science education researchers is vital to developing educational resources that promote evolutionary literacy, empowering students to address sustainability issues. Research is needed to enhance evolution education from early years, design effective curricula, create adaptable educational

resources, and engage religious students. The round table participants also stress the importance of research on how to facilitate effective collaborations and teacher empowerment.

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