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Competency-Based Learning in Biology Education: Content Analysis of the National Curriculum for Secondary School Biology in Greece

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Abstract: National education policy documents provide a pedagogical context for efficient learning outcomes. In Greece, a recent reform of the Secondary education Curricula aimed to shift from content-based and knowledge-transferred teaching to competency-based learning. The Greek Lower Secondary Biology Curriculum aligned interdisciplinary experiential learning with 21st century competencies, such as critical thinking, collaboration, communication, creativity, and digital literacy. The current study examined the pedagogical context of the reform and the depth of the alignment to 21st century competency-based learning. The qualitative and quantitative content analysis of the Curriculum was conducted by an independent coder and NVivo 11. Results revealed that the Lower Secondary Biology Curriculum focused on three main themes: 1. Epistemic competence as a core 21st century skill, 2. The student as an agentic, ethical, and responsible actor and 3. Learning, assessment, and metacognition as lifelong competence. Student-oriented, activity-based, experiential and sustainable conceptual pedagogy was emphasized and problem-solving, cooperative learning strategies were recommended, in order to produce critical scientific literate learners. Assessment also focused on scientific reasoning and social awareness among secondary school students. Findings highlight that competency-based Biology Curriculum design could provide a didactic context for the efficient integration of 21st century skills in secondary education.

Keywords: 21st century skills, biology education, Curriculum, pedagogy, competency-based learning, secondary education

I. INTRODUCTION

Education systems around the world are experiencing significant transformation. Globalization and the rapid technological progress reform educational practice beyond the mere transmission of knowledge, to foster a comprehensive set of cognitive, social, and digital competencies [1]. Citizens of the 21st century are required to have the ability to apply knowledge, skills, and attitudes in meaningful and transferable ways across disciplinary boundaries [2]. This shift is reflected in formal education policy documents, that sway from content-driven curricula to competency-based learning [3].

Educational and neurobiological research reveals that the development of competencies is necessary, in order to enhance the effectiveness of the learners [4]-[7]. Skills are based on and reinforced by the evolutionary and

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developmental axis of the learning process in *Homo sapiens*, combined with the interaction of the organism with the environment on a cellular, organismic and populational level [8], [9]. The human brain reorganizes and adapts to new stimuli, maximizing conceptual change. For example, neuroplasticity in areas of the parietal lobe, which are involved in the processing of numbers and quantitative data, plays an important role in the development of mathematical skills [10]. Similarly, the development of social skills, such as cooperation and communication, is located mainly in the frontal and temporal regions of the brain [11]. Social interaction leads to long-term strengthening of the corresponding synapses [12], [13], allowing for a better understanding of emotions and intentions, known as empathy [14], [15]. On the other hand, the use of information and communication technologies (ICT) directly affects the development of neural structures related to creativity, cooperation and critical thinking [16], [12]. Developing digital literacy skills strengthens the synapses involved in information processing and problem solving, increasing cognitive flexibility and the ability to adapt to new situations [17], [2]. Such neurobiological findings reinforce the opinion that, rather than being add-on to content learning, competency development should be viewed as integral to national education policy goals.

Various international frameworks refer to the integration of 21^{st} century skills in the learning process, including those proposed by the OECD, UNESCO, and the Partnership for 21^{st} century Learning. A skill is often considered a form of intelligence with a practical dimension, that reflects the utilization of theoretical knowledge in the context of some practical application [18]. A competency is a set of related but different skills, organized around an underlying construct intent [19]. Competencies combine disciplinary knowledge, cognitive skills, and socio-emotional dispositions, for an effective management of everyday problems [20]. According to Geisinger [21], the key 21^{st} century competency frameworks include cognitive or learning skills, such as critical thinking, creativity, collaboration, and communication (known as the 4Cs), interpersonal skills, such as collaboration, communication, and social awareness, intrapersonal skills, such as adaptability, flexibility, and self-direction, and technical or digital skills, such as proficiency with information and communication technology. Despite differences in terminology, most frameworks converge on a core set of competencies: critical thinking, problem solving, collaboration, communication, creativity, and digital literacy [2].

The development of competencies fosters the academic, professional, and civic engagement of students in 21^{st} century environments [22]-[25]. Competency-based learning (CBL) is a popular educational approach in Primary and Secondary education [26], in which progress is based on demonstrated mastery of clearly defined competencies rather than time spent in instruction [27]. Studies reflect on the importance of aligning competency development with different levels of education to ensure students are adequately prepared for each subsequent stage [28]-[30]. The variability of the ways in which these competencies are operationalized within curricula and classrooms, raises concerns about coherence and comparability across educational contexts [31].

Many scientific practices, such as inquiry, evidence-based reasoning, argumentation from evidence, ethical decision-making, and real-world problem solving, overlap substantially with 21^{st} century competencies [32], [33]. Therefore, competency-based learning in science education can provide a pedagogical context for authentic scientific practices and real-world challenges [34]. Student assessment processes such as PISA reveal that scientific literacy – the capacity to use scientific knowledge, to identify questions and to draw evidence-based conclusions in order to understand the natural world – is central for 21^{st} century students [35]. Science education policies tend to focus on the development of essential skills in different levels of proficiency, from low-achieving students to more scientifically literate [36] - [38].

Biology education holds a distinctive epistemic position within science education. It has been identified as a particularly fertile domain for competency-based learning that highlights systems thinking, and scientific argumentation [39]. The ability to reason across levels of biological organization requires student-oriented, constructivist and inquiry-based pedagogies and development of competencies in authentic contexts [40]. The conceptualization of core biological ideas such as evolution, homeostasis, genetics, gene-environment interaction, and environmental awareness, further supports the development of many 21^{st} century skills [41]. Due to its focus on living systems, variability, and multilevel causality, biological knowledge is integrated with scientific thinking: experimentation, causal reasoning, modelling, and interpretation of evidence [40].

Recent large-scale curriculum reforms in science education emphasize the importance of competency development; The Vision and Change initiative in undergraduate biology education, for example, calls for integrating core concepts with scientific competencies such as quantitative reasoning, modelling, and interdisciplinary thinking [39]. Similarly, the Framework for K–12 Science Education emphasizes the integration of disciplinary core ideas, scientific practices, and crosscutting concepts [34].

In Greece, national educational policy for more than a decade has been engaged in Curriculum reform, in order to be in line with the European Union key competences approach [42]. Recent Curriculum reforms have tried to shift secondary education from content-heavy syllabi towards competency-based learning. Greek education policy directives urge teachers to take part in a number of initiatives regarding the development of competencies, usually through school partnerships with government institutions, higher education institutions or stakeholders outside the school setting, such as museums [43]. The Institute of Educational Policy (IEP) is the scientific body under the Greek Ministry of Education that develops, revises, and evaluates Curricula for Primary and Secondary education, addressing issues from educational pedagogical research to publication of school textbooks and other teaching material. In 2022 it reshaped the Secondary education Curricula, in accordance to international educational imperatives [43], [22], [23]. A brief preliminary examination of the Secondary education policy documents, that is, Greek Government Education Policy Gazette [44], and Greek Biology Curriculum for Lower Secondary education (Gymnasium) [45], reveals a focus on the development of skills among learners of the 21st century. The documents emphasize interdisciplinarity and the development of transversal skills alongside conceptual understanding. The recommended pedagogical practices include inquiry-based learning, cooperative learning, problem solving, discussion, questioning, conversation, and learning by doing. Especially in Lower Secondary science education (Gymnasium), the reduced amount of syllabus enables teachers to integrate STEM approaches and multidisciplinary activities in the classroom [46].

While these reforms align to international educational trends, research on the pedagogical context and didactical transformation of 21st century skills in formal Greek Biology education remains limited. The need to examine national educational policy documents for an in-depth analysis of competency-based learning is particularly important because of the dearth of research studies in this area. This study addresses this gap by examining how 21st century skills are represented and articulated in the Greek Lower Secondary Biology Curriculum.

II. Methodological Approach

A. *Overall Design*

The current study was based on a mixed-methods design that used text analysis for subjective meanings and numerical data for trends. For a comprehensive understanding of the Greek Lower Secondary Biology Curriculum, which is a policy curriculum document, the analysis combined qualitative content analysis [47] and a qualitative thematic analysis framework, primarily informed by Braun and Clarke Reflexive Thematic Analysis [48]. Quantitative analysis was layered on top of qualitative thematic coding, which is consistent with qualitative-dominant mixed analytic design.

Since the main aim of the study was to analyse official policy documents regarding the development of 21st century skills in Secondary Biology education [49], the purposive sampling technique was used [50]. We chose to analyse the Greek Lower Secondary Biology Curriculum because it directs the teaching-learning processes in the lower secondary schools in Greece. In addition, it acts as the main guide for teachers and students, regarding the utilization of biology textbooks in schools. Finally, Lower Secondary education (Gymnasium) in Greece is compulsory, whereas non-compulsory Higher Secondary education (Lyceum) leads to a final student assessment that ensures the entrance in Higher education institutes (Greek public Universities), making the content and implementation of the corresponding Curriculum tight and exam-oriented.

B. *Data Analysis*

Qualitative content analysis was open and non-invasive. The analytic orientation was interpretivist and constructionist, with discursive sensitivity to student/science (biology)/competency interaction. It was assumed that the Curriculum language influences the educational content and that Curriculum documents construct subject positions and reflect governance rationalities. The analysis was primarily inductive, with secondary theoretical sensitization. Thus, themes represent discursive constructions and not objective features (Table 1).

The qualitative analysis followed a primarily inductive, non-linear logic, beginning with open coding of the document and progressing through axial clustering to theme development. Coding focused more on intent and its implications, allowing for research in relation to the era and social conditions of the document's creation, cohesion and coherence of the connecting ideas and vocabulary and style characteristics. The presence of interesting, important pieces of content was indicated by systematic reading of the text [51]. Codes were generated directly from the curriculum language. They were descriptive (e.g., "Digital integration in pedagogy"), in vivo (e.g., "Learning-to-learn competence") and conceptual (e.g., "Science as problem-solver"). Themes emerged from clustering the open codes based on conceptual similarity, discursive function and structural

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curriculum role. They derived from patterns within the data [48] and were later interpreted in relation to OECD, P21, and LifeComp framework models. No pre-imposed OECD or 21st century skill categories were used during coding and theoretical mapping occurred only after themes were developed. Naming was deliberate to reflect discursive construction (e.g., "Student as Epistemic Agent" rather than "Scientific Skills"). However, the analysis was not purely naive inductivism. The researcher was theoretically sensitized by competency-based education literature, OECD Learning Compass and 21st century skills discourse. This means that while codes were data-driven, interpretation of patterns was theoretically informed [48].

After theme generation, the quantitative content distribution was estimated. Frequencies and control of distribution of codes established a group of categories that were used to convert qualitative data into quantitative statistical data. Content patterns within the texts were analysed in a reproducible and systematic way, using qualitative and statistical methods [52]. An interpretive comparison between the curriculum's axial categories and themes and international educational policy documents (OECD Learning Compass 2030, P21 Framework and LifeComp Framework) was conducted.

TABLE 1
QUANTITATIVE CONTENT ANALYSIS METHODOLOGICAL LOGIC

Dimension	**Approach Used**
Primary method	Braun & Clarke Reflexive Thematic Analysis
Coding type	Open → Axial → Thematic
Logic	Primarily inductive
Theory role	Sensitizing, not structuring
Epistemology	Constructionist
Quantification	Secondary, post-thematic

To ensure the validity of the code labels and the reliability of the data, the document was also analysed with the help of NVivo 11 software. This software was considered most suitable because it can easily handle a large amount of text data [53], and provides different tools to address the research aim from different sources of data [54]. Four steps were used in Nvivo, that is, importing data, coding data, creation of framework matrices, and reporting of the findings. The document was imported as source in pdf format. Then the relevant text was coded as nodes. The relevant passages were coded in relevant nodes and child nodes [55]. The coding units were condensed after summarizing to get in-depth meanings of the text.

III. FINDINGS & RESULTS

The current study examined the importance of competency-based learning in science for Greek education policy through the analysis of the pedagogical and didactical context of the reformed Lower Secondary Biology Curriculum, regarding the development of 21st century skills. Findings showed a content-based organization of the new Curriculum into biological thematic areas, covering from the basic concept of life, the structure and function of organisms to contemporary issues such as biotechnology, genetic engineering and evolution. The document presented an analytical educational framework, which in general aimed to develop learning skills, cultivate biological literacy, and raise awareness of health, environmental and sustainability issues.

A. *Qualitative Analysis*

The Greek Lower Secondary Biology Curriculum outlined five (5) essential, interdependent sections (CS1-CS5), which collectively influenced its structure and effectiveness:

1. CS1: The characteristics of Lower Secondary school Biology (ΦΥΣΙΟΓΝΩΜΙΑ ΤΟΥ ΜΑΘΗΜΑΤΟΣ)
2. CS2: Aims, objectives and learning outcomes (ΣΚΟΠΟΘΕΣΙΑ Γενικοί Σκοποί, ΣΚΟΠΟΘΕΣΙΑ Ειδικοί Σκοποί – Γνωστικό αντικείμενο Βιολογίας)
3. CS3: Content (ΠΕΡΙΕΧΟΜΕΝΟ Θεματικά Πεδία)
4. CS4: Teaching methodology and corresponding pedagogical context (Διδακτική Μεθοδολογία και Παιδαγωγικό Πλαίσιο)
5. CS5: Assessment (Αξιολόγηση)

Across CS1-CS5, a total of n=73 initial open codes (CO1-CO73) were generated (Table 2). Regarding CS1, 13 codes emerged regarding science as socially embedded, science as solution discourse, competency discourse and moral–citizenship framing. This section strongly constructed the Curriculum as transformative, citizenship-oriented, future-facing and competency-driven. In CS2, 22 codes were generated. Emerging analytic clusters related to inquiry-based science and knowledge society discourse, with an ethical–sustainability orientation. The content focused on scientific literacy construction and social & digital competency integration The analysis of CS3 revealed a shift from aims to knowledge structuring and epistemic organization of Biology. The 13 codes clustered around systems and interconnectedness thinking, sustainability and the interface between science and society. The analysis of CS4 revealed a pedagogically dense and strongly competency-oriented content. The section shifted the Curriculum from knowledge content to the construction of knowledge. The 14 codes related to inquiry epistemology, student agency and the social and collaborative construction of knowledge. The analysis of the final section CS5 of the Curriculum was crucial, because assessment reveals what is truly valued in education policy. The 11 codes confirmed the Curriculum's deeper reflexive, competency-based and student-empowering orientation.

TABLE 2
OPEN CODES (CO) GENERATED FROM EACH OF THE FIVE SECTIONS (CS) OF THE LOWER SECONDARY BIOLOGY CURRICULUM DOCUMENT.

Section	**Section Content**	**Number of open codes**	**Content of open codes**
CS1	General characteristics of school biology	13	Biology as frontier science, Science beyond experts, Education for well-being, Biology addressing global crises, Science as problem-solver, Real-life relevance, Learner experience as resource, Learning-life integration, Critical thinking cultivation, Values development, Biological literacy, Active ethical citizenship, Bioethical awareness
CS2	Aims, objectives and learning outcomes	22 General Aims CS2/GA=10 Special Aims CS2SA=12	Foundational disciplinary knowledge, Integrated knowledge–skills framework, Informed decision-making, Developmentally responsive agency, Active participation in knowledge society, Knowledge society framing, Responsible personal and environmental action, Initiation into research practices, Empirical observation emphasis, Leveraging student interest / Conceptual understanding of biology, Scientific explanation competence, Application to everyday life, Inquiry skills development, Evidence-based reasoning, Scientific argumentation, Health & environmental decision-making, Bioethical sensitivity, Positive disciplinary identity, Collaborative scientific work, Digital literacy in science, Sustainability awareness
CS3	Content	13	Thematic structuring of knowledge, Ecological interconnectedness, Life maintenance processes, Evolutionary perspective, Sustainability integration, Science–society interface, Applied science orientation, Biotechnology as future science, Health relevance, Environmental crisis discourse, Ethical dimension of science, Knowledge–practice linkage, Interdisciplinary orientation
CS4	Pedagogy	14	Inquiry-based pedagogy, Active learner positioning, Hypothesis generation, Experimental design competence, Data interpretation skills, Collaborative pedagogy, Structured group work, Digital integration in pedagogy, Experiential anchoring, Differentiated instruction, Critical thinking reinforcement, Creativity promotion, Reflective practice, Learning-to-learn competence
CS5	Assessment	11	Formative assessment orientation, Feedback-driven learning, Process-oriented assessment, Self-assessment practice, Peer assessment practice, Metacognitive development, Competency-based assessment, Affective domain assessment, Multimodal assessment methods, Continuous evaluation, Assessment as support mechanism
	TOTAL	**n=73**	

Conceptually related open codes produced seven (7) axial categories (CA-CG) (Table 3). Axial clustering produced five (5) preliminary themes (PT1-PT5) to ensure internal coherence, external distinction, conceptual clarity and thematic explanatory power (Table 4). PT1 framed science as solution-oriented and sustainability-driven. In PT2 the student was constructed as an active researcher and not a passive knowledge recipient. The focus of PT3 was citizenship, PT4 highlighted knowledge as inseparable from skills and PT5 emphasized on learning as process related to metacognition, not an educational product.

TABLE 3
AXIAL CATEGORIES (C) OF THE LOWER SECONDARY BIOLOGY CURRICULUM DOCUMENT.

Category	**Category content**
CA	Science as Socially Embedded and Future-Oriented
CB	Scientific Literacy and Epistemic Competence

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CC	Student Agency and Decision-Making
CD	Competency and 21st Century Skills Discourse
CE	Knowledge Architecture and Curriculum Structuring
CF	Assessment as Developmental Infrastructure
CG	Core Disciplinary Content and Identity

TABLE 4
PRELIMINARY THEMES (PT) OF THE LOWER SECONDARY BIOLOGY CURRICULUM DOCUMENT.

Preliminary theme	Title of preliminary theme
PT1	The Curriculum Constructs Science as a Transformative Social Force
PT2	Student as Epistemic Agent
PT3	Student as Ethical and Responsible Citizen
PT4	Competency-Based, Future-Oriented Education
PT5	Learning as Process, Not Product

Preliminary themes were checked against axial categories and policy discourse consistency. Substantial overlap was noticed between PT3 and PT4; both relied heavily on inquiry, critical thinking, evidence-based reasoning and knowledge–skills integration. As different faces of the same representational logic, PT3 and PT4 were merged into a broader theme focused on epistemic competence as a 21st century skill. Also, PT1 operated as a macro-discursive framing that supplied the normative justification for skills and anchored skills in sustainability and ethics. Therefore, it was reconceptualized as an overarching contextual frame. Finally, PT5 included assessment but also metacognition, self-regulation and reflexivity, so it was expanded and sharpened, explicitly linking assessment to self-regulatory competence. After iterative reviewing, redefining, and re-clustering, three (3) interrelated final themes (FT1-FT3) were generated (Table 5):

1. Epistemic competence as a core 21st century skill
2. The student as an agentic, ethical, and responsible actor
3. Learning, assessment, and metacognition as lifelong competence

TABLE 5
FINAL THEMES (FT) OF THE LOWER SECONDARY BIOLOGY CURRICULUM DOCUMENT.

Final theme	Content of final theme	Key features	Interpretation
FT1	Epistemic Competence as a Core 21st Century Skill	Inquiry-based learning Hypothesis generation Evidence-based reasoning Data interpretation Scientific argumentation	21st Century Skills are disciplinarily embedded, not abstracted. Critical thinking is articulated as scientific epistemic practice.
FT2	The Student as an Agentic, Ethical, and Responsible Actor	The learner is someone who: Makes informed decisions Acts responsibly in health and environmental contexts Participates in a knowledge society Exercises ethical judgment	21st Century Skills are articulated as agency, not employability. The student is constructed as a decision-maker, a responsible citizen, a sustainability actor.
FT3	Learning, Assessment, and Metacognition as Lifelong Competence	Assessment and pedagogy converge to construct: Learning-to-learn Self-assessment Peer assessment Reflection Metacognitive awareness	21st Century Skills are represented as self-regulatory capacities, cultivated through formative processes.

The context of all final themes was "Biology education as a response to future societal challenges".

Discursive qualitative analysis of the Curriculum focused on key components of the educational triangle, meaning the student, the teacher and the content [56]. Findings revealed that throughout the document students were constructed as highly agentic subjects. Relevant descriptions included novice researchers, sustainability-oriented citizens, reflective learners, collaborators and digital actors. They were characterized by scientific thinking, critical and moral responsible decision-making. Teachers were presented implicitly as orchestrators and not transmitters of knowledge, with descriptions such as facilitators of inquiry, designers of experiential environments, differentiation strategists, assessment coaches, feedback providers, mediators of ethical dialogue. Science of Biology was framed as socially embedded, crisis-responsive, innovation-driven and ethically negotiated, which legitimizes the emphasis on 21st century skills.

The interpretive comparison between the six (6) competency-related axial categories (CA-CG) and the three (3) final themes (FT1-FT3) of the Curriculum, and three (3) international educational policy documents -OECD Learning Compass 2030 [26], P21 [22], [57] and LifeComp [58] Frameworks- showed depth of convergence, emphasis, and ideological positioning (Table 6).

TABLE 6
COMPARATIVE SYNTHESIS OF THE LOWER SECONDARY BIOLOGY CURRICULUM AND OECD, P21 AND LIFECOMP EDUCATIONAL FRAMEWORKS.

Dimension	**OECD**	**P21**	**LifeComp**	**Curriculum Alignment Strength**
Agency	Central	Present	Strong	Extremely strong
Sustainability	Strong	Present	Moderate	Strong
4Cs	Embedded	Core	Embedded	Strong
Digital skills	Included	Strong	Limited	Strong
Ethical responsibility	Transformative competency	Civic literacy	Empathy Well-being	Strong
Formative assessment	Strong	Moderate	Strong	Strong
Epistemic scientific literacy	Strong	Moderate	Limited	Strong disciplinary emphasis

More specifically:

- In regard to CA (Science as Socially Embedded and Future-Oriented), the Curriculum mirrored OECD's future-of-society orientation almost structurally. Findings showed a very strong alignment with OECD transformative competencies, such as creating new value, reconciling tensions and taking responsibility, with the emphasis on sustainability and global challenges. Findings also revealed a strong alignment with LifeComp Framework, with multiple references to empathy and collaboration, even though LifeComp framed sustainability more through personal-social responsibility, while the Curriculum embedded it through scientific literacy. The alignment with P21 Framework was moderate: P21 treated global awareness, civic and environmental literacy as one strand among others, whereas the Curriculum embedded them centrally.
- The second axial category CB (Scientific Literacy and Epistemic Competence) conceptualized knowledge as applied and transferable, identical to OECD's positioning. The relevant content of the Curriculum showed significant alignment with critical thinking and information literacy but was more disciplinarily grounded regarding scientific inquiry processes, in contrast to P21 and LifeComp Frameworks.
- The study also revealed extremely strong OECD and LifeComp alignment with CC (Student Agency and Decision-Making), especially in relation to responsibility, decision-making, participation in knowledge society, collaboration and self-regulation. Initiative and self-direction as well as leadership and responsibility were present but less theoretically elaborated. P21 framed agency as workplace preparedness; OECD framed it as societal transformation. The Curriculum aligned more with OECD's broader civic framing.
- Regarding CD (Competency and 21st Century Skills Discourse), alignment to all three international frameworks was strong. All content explicitly rejected knowledge-only models and integrated 4Cs, with the exception of ICT literacy, which was excluded from LifeComp.
- Analysis showed that CE (Knowledge Architecture and Curriculum Structuring) aligned with interdisciplinary learning and real-world problems, similarly to OECD and P21. However, P21 was more skill taxonomy than epistemic restructuring. There was no direct LifeComp alignment.
- Findings for CF (Assessment as Developmental Infrastructure) showed very strong alignment with formative assessment, reflection and metacognition, which were strongly supported by OECD, as well as self-assessment and personal development, reflexive processes strongly supported by LifeComp.

B. *Quantitative Analysis*

Quantitative analysis of the Lower Secondary Biology Curriculum focused on competency-based education and 21st century skills. The unit of analysis was the open code (n=73), codes were the measurable indicators of curricular emphasis and categories were the analytical variables. Frequencies and percentages revealed the structural weight of discourse with strong emphasis on competency-related domains, such as categories CD, CA and CB (Table 7).

TABLE 7
FREQUENCY DISTRIBUTION BY AXIAL CATEGORY (CA-CG) OF THE LOWER SECONDARY BIOLOGY CURRICULUM.

Category	n	Percentage
CA	13	17.8
CB	12	16.4
CC	11	15.1
CD	14	19.2
CE	8	11.0
CF	5	6.8
CG	10	13.7
TOTAL	**73**	**100%**

The analysis of competency-oriented categories showed that nearly 7 out of 10 codes (68.5%) reflected competency-based logic (Table 8). Almost 2 out of 10 codes (20.5%) explicitly represented core 21st century skills constructs, with the emphasis on collaboration, critical thinking, digital literacy, decision making and the ability to assess oneself and others (Table 9). Nearly one-fifth (17.8%) of the coded Curriculum related to sustainability and responsibility discourse. In regard to the assessment orientation measure, although numerically smaller (6.8%), codes were conceptually dense and developmentally aligned, with the emphasis on formative, metacognitive assessment.

TABLE 8
COMPETENCY-BASED EDUCATION INTENSITY OF THE LOWER SECONDARY BIOLOGY CURRICULUM.

Competency-oriented categories	n	%
Epistemic competence (CB)	12	16.4
Agency & decision-making (CC)	11	15.1
21st century skills (CD)	14	19.2
Real-world application (CE)	8	11
Developmental assessment (CF)	5	6.8
TOTAL	**50**	**68.5%**

TABLE 9
21ST CENTURY SKILLS INTENSITY OF THE LOWER SECONDARY BIOLOGY CURRICULUM.

Explicit 21st century skill indicators	n	%
Critical thinking	2	2.7
Creativity	1	1.4
Collaboration	3	4.1
Digital competence	2	2.7
Metacognition	1	1.4
Learning-to-learn	1	1.4
Decision-making	2	2.7
Self/peer assessment	2	2.7
Communication-related	1	1.4
TOTAL	**15**	**20.5%**

Textual and conceptual pattern analysis showed that the Lower Secondary Biology Curriculum was quantitatively structured around transferable skills, not biological content coverage (5:1 ratio). There was a distinct decentralization of content, with scientific knowledge reframed as a medium for competence development. The integration of 21st century skills in the Curriculum was systemic and not superficial, with a distribution of relevant codes across many different sections.

IV. CONCLUSIONS

The current study analyzed the Greek Lower Secondary Biology Curriculum to understand national policy recommendations regarding the integration of 21st century skills in Secondary Biology education. Key thematic axes of the document included the structure and function of cells, metabolic activity, reproduction, health and the immune system, genetics, biotechnology, ecology and evolution. Different thematic fields were functionally linked to each other but also to everyday life and society, especially in relationship to contemporary social and ethical issues, such as bioethics, sustainability, sustainable development and disease prevention.

Our study showed that the Secondary Biology Curriculum focuses on scientific literacy, interdisciplinary understanding of biological concepts and the development of students' research skills, so that students can formulate questions, conduct experiments and explain documented conclusions. Keeping the contemporary scientific context and social needs in mind, the Curriculum aims to develop active citizenship and responsible participation in environmental and social issues. References to competencies such as creativity, critical thinking, inquiry, self-motivation and collaboration are frequent and explicit. Technology also has a prominent position as a teaching tool [59].

The aim of the Greek education policy document is to construct Biology education as a mechanism for shaping future-ready, ethically grounded, scientifically literate citizens. The Curriculum reflects a hybrid governance discourse with a clear hierarchy: primary alignment to OECD Learning Compass 2030, secondary alignment to P21 and a complementary alignment to LifeComp framework. It holistically adopts the P21 framework, which supplies operational skill language in order to incorporate all key skill categories, with an emphasis on the 4Cs and the scientifically literate, active citizen. These skills are embedded in learning objectives and framed as essential outcomes of Biology education. However, the Curriculum moves beyond P21's generic "critical thinking" toward an OECD-style epistemic competence model, beyond skill acquisition to subject formation. The development of 21st century competencies is constructed primarily through practical ways of knowing and doing science, not through transmission of knowledge and generic skills. The document cultivates agency through scientific literacy, while ethical reflection and psychosocial depth are supplied by the LifeComp framework. This is consistent with a high-density competency-based education model that aligns strongly to OECD's concept of student agency and LifeComp's social responsibility dimension.

Greek education policy designed the Biology Curriculum to didactically incorporate a developmental student assessment. Its pedagogical nature is not evaluative but with an emphasis on formative assessment that informs and guides the learning process, supporting self-assessment and the adaptation of teaching. This reflects a shift from learning performance towards OECD's growth and reflection logic and LifeComp's self-regulation and personal development educational model.

The reform of the Greek Lower Secondary Biology Curriculum reflects the ever-increasing demands for scientifically educated citizens, capable of assessing and addressing complex health, environmental and technological problems [60]. The emphasis on critical and creative thinking shows a clear adaptation to modern scientific developments and social needs [61]. The main goal of the Curriculum is to improve students' 21st century skills, as proposed by international competency-based frameworks [22], [26], [57], [58]. The use of ICT further promotes personalized learning and facilitates access to advanced educational tools, while formative assessment enhances the flexibility and adaptability of teaching [62]. The Curriculum remains a governance document, in which science (Biology) is a societal problem-solving tool, students are the responsible agents of future systems and learning is a continuous and self-regulated process [63]. In the long term, the successful implementation and ongoing evaluation of the Lower Secondary Biology Curriculum will contribute to the creation of a more dynamic, research-based and responsible school community and to the fruitful connection of education with the real challenges of the time [64].

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