Compendium of Educational Innovation:

Interdisciplinary Methods and Digital Readiness

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Compendium scope statement ↘

Project Title	InterEd; Interdisciplinary Approaches for Innovative Education
Compendium Overview	The general scope of the compendium is to guide secondary school teachers, education policymakers, higher education institutions (HEIs), and other interested stakeholders in integrating interdisciplinary teaching and learning approaches into secondary education. It aims to address the limitations of traditional, subject-specific curricula by promoting methods like Phenomenon-Based Learning (PhenoBL) that foster a better understanding of the interconnected world.
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UNIVERSITY of NICOSIA

DIRECTORATE OF SECONDARY EDUCATION OF PIERIA GREECE

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Interdisciplinarity in Secondary Education

Abstract

This chapter examines the historical and theoretical underpinnings of interdisciplinary teaching in secondary education, highlighting its longstanding tradition in ancient Greek education and its continued relevance in modern pedagogical practice. This approach integrates multiple disciplines to provide students with cohesive learning experiences and equips them with the skills to address complex, real-world problems. Notable figures such as John Dewey have advocated for interdisciplinary learning, emphasising the importance of connecting personal experiences with academic subjects. The definitions of interdisciplinarity, multidisciplinarity, and transdisciplinarity are clarified with an emphasis on synthesis and integration of knowledge.

The chapter outlines the benefits of interdisciplinary education, including increased student engagement, creativity and problem-solving. Furthermore, it presents global case studies, including Finland, Singapore, and Ireland, where interdisciplinary modules have been shown to foster creativity and critical thinking. It is vital that teachers are able to foster interdisciplinary understanding, and this can be achieved most effectively through collaborative teaching.

Introduction

The interdisciplinary approach in education, frequently perceived as a modern advancement, however it has deep historical roots. This educational strategy, which integrates multiple subjects to provide a more cohesive and comprehensive learning experience, has been utilized for centuries. Interdisciplinarity, and particularly the related notion of consilience, can be traced back to philosophers in ancient Greece. Consilience which often attributed to Pythagoras and his followers, is the idea that there is a unity of knowledge, a single rational order to the cosmos (Ralston, 2010).

Actual curriculum integration for interdisciplinary learning was demonstrated by the Herbartian movement, which started in the late 1800s (Drake & Burns, 2004). Tuiskon Ziller, a follower of Herbart, endorsed the concept of "integration of studies" centered on certain themes as a means of bringing disparate and isolated disciplines together (Klein, 2002). During the first half of the 20th century, the underlying concepts of interdisciplinary learning can be seen in the history of the progressive education movement in the United States. Based on this movement, interdisciplinary learning today is close to pedagogical progressivism. Leading the educational movement of pedagogical progressivism, Dewey was a pioneer who offered valuable perspectives on the significant ramifications of modern interdisciplinary learning. According to Dewey, a child-centered learning environment should incorporate the concepts of "continuity" and "interaction" into children's educational experiences (Yang, 1999). He believed curriculum based on personal experiences led to natural connections between prior knowledge and the learning of new material. On the other hand, subjects that are purposefully divided may make it more difficult for students to identify and understand the connections between the relevant subjects. After the launch of Sputnik (1957), educators have designed interdisciplinary curricula and conducted research projects associated with interdisciplinary learning and teaching based on the nature of interdisciplinary theories and methods (Klein, 1990).

Professor Julie Thompson Klein of the humanities at Wayne State University released the first significant book on interdisciplinarity in 1990. Her book is entitled Interdisciplinarity: History, Theory and Practice. Klein gave an overview of all the published research in all domains of knowledge rather than arguing for a certain approach. She observed that:

> Interdisciplinarity has been variously defined in this century: as a methodology, a concept, a process, a way of thinking, a philosophy, and a reflexive ideology. It has been linked with attempts to expose the dangers of fragmentation, to reestablish old connections, to explore emerging relationships, and to create new subjects adequate to handle our practical and conceptual needs. Cutting across all these theories is one recurring idea. Interdisciplinarity is a means of solving problems and answering questions that cannot be satisfactorily addressed using single methods or approaches. Whether the context is a short-range instrumentality or a long-range reconceptualization of epistemology, the concept represents an important attempt to define and establish common ground (Klein, 1990, p. 196)

Today the term "interdisciplinary teaching" is widely used in all K-12 educational fields due to a growing understanding of the inherent value and advantages of interdisciplinary teaching. Without a doubt, interdisciplinary understanding informed by many disciplinary backgrounds is necessary due to the complexity of the natural system and the scientific challenges that accompany it. This understanding is something that only one discipline cannot or may not be able to provide.

Schijf et al. (2023) provided an example for understanding the need of interdisciplinarity. The COVID-19 pandemic, for instance, shows that dealing with this situation requires more than just medical knowledge. Social scientists could provide insight into human behaviour that contributes (or not) to a way out of this pandemic. Individuals with backgrounds in fields like economics or law are also necessary to understand the societal and human effects of pandemic-related policy. However, detailed disciplinary academic expertise is required in addition to interdisciplinary approaches, for example, to perform specific analyses or to develop (technical) solutions.

1.1 Definition of interdisciplinary

In education, interdisciplinary, multidisciplinary, and transdisciplinary approaches refer to different ways of integrating knowledge and methods from various disciplines. According to Klein (1990) defined multidisciplinarity as "a process for providing a juxtaposition of disciplines that is additive, not integrative", interdisciplinarity as "a synthesis of two or more disciplines [that] establishes a new level of discourse and integration of knowledge", and transdisciplinarity as an approach that "provides holistic schemes that subordinate discipline, looking at the dynamics of whole systems". Specifically, while multidisciplinary efforts concatenate disciplinary knowledge (Klein, 1996), or present it in 'serial fashion' (Richards, 1996), they do not achieve the synthesis or integration of disparate disciplinary knowledge into a cohesive whole that many argue is the marker of interdisciplinarity (Lattuca, 2001). Furthermore, interdisciplinary instruction combines closely linked concepts and skills from two or more disciplines, while transdisciplinary instruction takes this one step further to bring together knowledge and skills from multiple disciplines through projects designed to tackle real-world problems (Johnson et al., 2020). In an interdisciplinary curriculum, disciplines remain somewhat distinct, but their connections are stronger and made explicit. Boundaries are blurred when subjects are organized around a key interdisciplinary concept such as sustainability, or around complex interdisciplinary skills such as critical thinking or competencies such as intercultural competency. According to Drake and Reid (2020), interdisciplinary projects offer a contect for the investigation and blending of several subjects.

A vast literature across many fields including education yields many definitions of interdisciplinary. Variations in the use of the term suggest that teachers in the same educational programs may have differing views of what an education that stresses interdisciplinarity entails (see Carp 2001; Holley 2009; and Lattuca and Knight 2010).

Interdisciplinary teaching is related to holistic teaching which uses knowledge, skills and learning outcomes in different subject areas to clarify any issue or phenomenon (Yıldırım, 1996). Cone et al. (1998) described interdisciplinary teaching as an approach that integrates two or more subject areas into a meaningful association to enhance and enrich learning within each subject area. The most important advantage of interdisciplinary programs is to connect students to the real world, whereas traditional teaching environments fail to succeed (Yıldırım, 1996). Rowntree (1982) defines the interdisciplinary approach as “one in which two or more disciplines are brought together, preferably in such a way that the disciplines interact with one another and have some effect on one another’s perspectives” (p. 135).

Most definitions share an emphasis on the use and integration of concepts, knowledge, and methods from more than one academic discipline, to enhance students’ understanding of some phenomenon or problem (e.g. Mansilla et al., 2000; Klein & Newell, 1997; Lattuca et al., 2004).

Interdisciplinary in a school can be achieved under specific circumstances as Lenoir and Hasni (2016) supported. They proposed six foundational ideas that characterize quality school interdisciplinarity: (1) interdisciplinarity cannot exist without disciplines; (2) interdisciplinarity is not an accumulation of different disciplinary perspectives; (3)“interdisciplinarity in education belongs to the means, rather than the ends” (p. 2449); (4) there are no hierarchical relations among disciplines, which are treated equally; (5) three different interdisciplinary perspectives (logics) were emphasized by the authors, and “[. . .] these three logics of meaning, functionality and affectivity are complementary and should be interwoven when using interdisciplinary approach in teaching practices” (p. 2450); and (6) collaboration among teachers is crucial in an interdisciplinary approach.

1.2 Interdisciplinary and teaching

Following the above definitions, interdisciplinary competence could be characterized as a tool which combines and integrates information into a complex interdisciplinary knowledge structure focused on a particular theme. For example, the interactions between the individual and societal norms can be explored in historical and political dimensions; analyzed philosophically; and expressed in literature, film, or visual art. Furthermore, interdisciplinary study of a historical period may be less concerned with facts and dates than with how people of the time asked questions or how they expressed their values in artistic forms or through cultural symbols (Ivaniskaya et al., 2002). This approach shifts from the programmatic focus from memorization of facts to focus on a central theme, application of knowledge relative to this theme, and reflection on the thinking process.

Lenoir and Hasni (2016) presented four arguments showing the relevance of interdisciplinarity's use in teaching. First, they mentioned that interdisciplinarity requires teaching-learning situations that are meaningful to students. Second, interdisciplinarity calls for the use of the pragmatic constructionist epistemology. Real-life situations allow students to invest themselves based on their life experiences, so that they can inter-subjectively debate their different conceptions, and then, with the teacher's help, progress toward the use of scientific approaches. Their third contribution has to do with the need for complementarity and overlap in the scientific processes. Interdisciplinary can support the development of integrating learning processes (e.g., conceptualization, problem-solving, communicational). For instance, to produce an experiment protocol without having first conceptualized the experiment's components; and the results, for their part, require a communicational approach. Fourth, the authors pointed out that interdisciplinarity is meaningful if metacognitive processes are introduced and promoted by the teacher, and if they are applied by the teacher. Teachers usually teach knowledge, sometimes by making links between different school disciplines, but they forget or neglect the metacognitive processes that are indispensable to ensure effective learning.

Interdisciplinary education could be achieved through a considerable amount of encouragement and guidance from teachers. Teachers are the most important agents in the process of realizing interdisciplinary teaching. Therefore, they have to develop an interdisciplinary understanding of a particular concept and recognize an important pattern of information in order to provide high-quality interdisciplinary instruction.

Integrative teaching (e.g., interdisciplinary, multidisciplinary, cross-disciplinary, etc.) has been linked to numerous characteristics that may benefit middle-level learners including increased student engagement, motivation, and achievement (Applebee, Adler, & Flihan, 2007) as well as the synthesis of knowledge that comes from exploring topics and ideas through multiple lenses (Lee, 2007).

Interdisciplinary approaches, supporters claim, have the potential to increase student engagement, raise achievement, and reinvigorate stale teaching; they also reflect “real world” problems in which many disciplines and perspectives may be brought to bear (Beane, 1997; Jacobs, 1997; Tchudi & Lafer, 1996). Others have noted, however, that interdisciplinary curricula require time and resources that are not usually available, are often superficial, and easily degenerate, with one of the integrated subjects dominating the curriculum at the expense of the others (Adler & Flihan, 1997).

Several facilitators and barriers are suggested by Spelt et al. (2009)2 to affect the success of an interdisciplinary program after its implementation. First, several student conditions are necessary to learn interdisciplinary skills, i.e., curiosity, respect, openness, patience, diligence, self-regulation, social experiences, and educational experiences. Second, several learning environment conditions facilitate a program’s success, i.e.: 1) balance between disciplinarity and interdisciplinarity, 2) disciplinary knowledge inside or outside courses on interdisciplinarity, 3) an intellectual community focused on interdisciplinarity, 4) expertise of teachers on interdisciplinarity, 5) consensus on interdisciplinarity, 6) team development and team teaching, 7) pedagogy aimed at achieving collaboration, and 8) assessment of interdisciplinarity. Third, necessary learning process conditions are suggested, i.e., education should be phased with gradual achievement, linear, iterative, and aimed at achieving interdisciplinarity and promote reflection.

1.3 Interdisciplinary and students

The literature in the last two decades has arrived at the conclusion that students in interdisciplinary programs perform academically as well as, and sometimes better than, their counterparts from traditional programs (e.g., Brough & Pool, 2005; Hinde, 2005; Erickson, 2008; Drake & Reid, 2018). Research demostarted the advantages of interdisciplinary approach in the affective outcomes including self-regulation, prosocial attitudes, emotional health, creativity and motivation (see, for example, Edwards and Willis, 2000; Consortium of National Arts Education Associations, 2002; Durlak et al., 2011). Interdisciplinary teaching practices give students more effective and fulfilling educational experiences (Jacobs, 1989). Such an interdisciplinary approach makes teaching-learning more active and provides students with the chance to enhance their creative thinking skills. Furthermore, this approach positively influences students' participation in the course (Serkan & Aybek, 2020; Aybek, 2001).

Based on OECD (2018) creative thinking is one of the most important competencies for students to succeed in life and society. Singapore, Korea, Canada, Australia, New Zealand, Estonia and Finland (in descending order) are the highest-performing systems in creative thinking, with a mean score of 36 points or above – significantly above the OECD average (33 points). Students in Singapore score 41 points on average in creative thinking. Another interesting finding is that most countries and economies that scored above the OECD average in creative thinking outperformed the OECD average in mathematics, reading and science. Czechia, Hong Kong (China), Macao (China) and Chinese Taipei performed at or below the OECD average in creative thinking despite scoring above the OECD average in mathematics, reading and science. (OECD, 2024). Some countries integrated opportunities to develop creative thinking in their curriculum by introducing dedicated interdisciplinary or ”subject-free” modules. Specific examples from Finland, Singapore and Ireland are following.

Finalnd’s 2014 national curriculum introduced that schools need to offer at least one interdisciplinary module annually. Since creative thinking encourages teachers and students to look across disciplines, this straightforward approach both demands and empowers teachers to work in ways to foster creativity (West, 2016). This strategy can optimise instruction time and content coverage by emphasising connections across knowledge domains, because in interdisciplinary learning, the content and skills that learners practice are defined by the questions or themes that they work on rather than a strict separation of disciplines or subjects. Greater interdisciplinarity allows for the delivery of pedagogy around more contextualised and authentic problems, giving opportunities for less fragmented and more meaningful learning circumstances for students as well as increasing educators’ professional learning and accountability through collaborative teaching and planning (OECD, 2013]).

In Singapore, an elective course in secondary education, the Applied Learning Programme, focuses on interdisciplinary learning and provides opportunities for students to develop creative thinking by generating relatively novel and appropriate ideas or products in authentic society and industry environments. The programme can also be applied to more specific thematic areas (e.g. STEM, language). An alternative course, the Learning for Life Programme, gives the chance to students to creatively design activities and programmes (among other outputs) for the benefit of their communities (Baer & Kaufman, 2005).

Finally in Ireland, in order to counteract the possible detrimental effects of standardized testing regimes on schools' innovative thinking, students can opt to undertake a “transition year” that bridges the country’s junior and senior education cycles. The one-year programme allows students to focus on their personal, social and vocational development in the extended absence of examination pressures. Approximately 75% of schools in the country offered the programme in 2022 (OECD, 2023). As part of their transition year, students can participate in different initiatives, such as The B!G iDEA, which aims to put creative thinking at the centre of Ireland’s secondary education system through experiential learning and mentorship. Supported by the broader Creative Ireland programme and industry partners, the B!G iDEA is a 15-week, practically-oriented programme developed to empower students to use their creativity to address the main issues facing society.

Some argue that interdisciplinary study better prepares students for work and citizenship by developing higher-order cognitive skills such as problem-solving, critical thinking, and the ability to employ multiple perspectives (e.g., Hursh, Hass, & Moore, 1983; Newell, 1990; Newell & Green, 1982). Based on a recent report by OECD (2019), those skills ‘prepare young people with required competences to live sustainable, fulfilled and healthy lives in the rapidly changing world of the 21st century’ (p.3). Examples of such skills include engaging students in hands-on activities that allow them to discover new concepts and develop new understandings (Satchwell & Loepp, 2002), providing students with real-life problem-solving activities (Cunningham et al., 2020; Dailey et al., 2018; Hernandez et al., 2014), that can potential enrich high-level thinking skills (Kelley & Knowles, 2016) and improving conceptual understanding and academic performance (Nite et al., 2017).

A 21st-century skills-based curriculum pivots away from content acquisition and rote memorization to focus on the skills and abilities that will best serve our generation of young minds. Student engagement and hands-on, interdisciplinary learning are championed over conferring information.

For example, research claims that the interdisciplinary STEM approach promotes the above identified skills as it starts with a real-world problem or issue and at its core is the engagement of students in the critical thinking and problem solving, and the building of dispositions towards STEM subjects, that will prepare students for productive futures, rather than subject-specific content and skills (Tribaut et al., 2018).

Interdisciplinarity is an encouraging approach to the development of values and skills such as creativity, critical thinking, collaboration, and communication (McPhail, 2018). Furthermore, interdisciplinary is the ability to synthesize or integrate and could be characterized as a beneficial learning outcome of interdisciplinary education. In that case, the learning outcome is called interdisciplinary understanding or interdisciplinary thinking. Boix Mansilla et al. (2000, p. 219) proposed the following definition of interdisciplinary understanding, “The capacity to integrate knowledge and modes of thinking in two or more disciplines or established areas of expertise to produce a cognitive advancement—such as explaining a phenomenon, solving a problem, or creating a product—in ways that would have been impossible or unlikely through single disciplinary means.” According to this definition, interdisciplinary thinking can be considered as a complex cognitive skill that consists of a number of subskills (Van Merriënboer, 1997), such as the ability to change disciplinary perspectives and create meaningful connections across disciplines. The ability to think interdisciplinary takes time to develop, and it can take students a long time to reach a sufficient degree of proficiency. Last but not least, students need help in order to be able to synthesize two or more disciplines.

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Chapter 2 - Introduction to Phenomenon-Based Learning (PhenoBL)

Abstract

This chapter introduces Phenomenon-Based Learning (PhenoBL), a transformative educational approach from Finland that shifts the focus from traditional subject-centred teaching to interdisciplinary exploration of real-world phenomena. PhenoBL encourages students to investigate complex, authentic challenges, such as climate change or global health crises, thereby promoting critical thinking, problem-solving and collaboration. By placing an emphasis on the practical application of knowledge, this methodology is well-positioned to equip students with the skills they need to navigate modern complexities.

Digital tools such as interactive simulations and virtual labs are effective learning aids, while assessing schools' digital readiness is a crucial step in implementation. The chapter examines PhenoBL's roots in constructivism and phenomenology, as well as its integration into Finland's education policies, which have inspired global adoption.

Introduction

This chapter introduces Phenomenon-Based Learning (PhenoBL) educative practice such a learning style-model from Filand to the Future of Education. In the chapter transformative phBL approach to education, particularly in secondary schools, by focusing on real-world phenomena as the central axis of learning be represented. This methodology shifts from traditional subject-centered teaching to interdisciplinary exploration, where students investigate complex issues that span multiple disciplines. By immersing students in relevant, authentic challenges such as climate change, urbanization impacts, or global health crises, PhenoBL cultivates critical thinking, problem-solving, and collaboration skills. Moreover, it prepares students for the complexities of the modern world by emphasizing practical application of knowledge. The integration of digital tools further enhances PhenoBL, offering interactive simulations, collaborative platforms, and virtual labs that facilitate hands-on exploration and deepen understanding. Assessing schools’ digital readiness is crucial for effective PhenoBL implementation, ensuring access to necessary resources and fostering innovative teaching practices.

This introductory framework sets the stage for exploring recent technological innovations like interactive apps, online platforms, and educational games that support interdisciplinary learning, enriching students' educational experiences through dynamic, interactive engagement with complementary theories and concepts. Based on the results of primary and secondary data, some practical guidelines will be provided.

2.1 The background of Phenomenon-based learning

Phenomenon-Based Learning (PhBL) has diverse origins and cannot be strictly classified as a theory or method; rather, it is an approach grounded in constructivism, pragmatism, and phenomenology (Wolff, 2022a, in press). Although the principles of PhBL remain somewhat ambiguous (Wolff, 2022a, in press), the concept of phenomena and PhBL has gained considerable attention and inclusion in Finnish educational policies. The 2014 national curriculum for basic education in Finland emphasizes phenomena-based and integrative learning as foundational teaching strategies (Finnish National Board of Education, 2014). Since the introduction of this curriculum, Finnish schools have implemented extended multidisciplinary learning modules that foster collaboration across various subjects (Finnish National Board of Education, 2014, 4.4 Integrative Instruction and Multidisciplinary Learning Modules). Phenomenon-Based Learning (PhBL) is frequently rooted in inquiry-based learning (Hakkarainen, Lonka, & Lipponen, 2004), where knowledge and understanding are collaboratively constructed and learners take on active roles. Additionally, PhBL is philosophically anchored in phenomenology (Küpers, 2012; Merleau-Ponty, 2014; Wolff et al., 2019; Østergaard et al., 2008).

Interest in Phenomenon-Based Learning (PhBL) began to emerge in European curricula starting in 2015, particularly influenced by the Finnish education system (Garner, 2015). The book "Phenomenal Learning from Finland" showcases Finland's journey toward 21st-century competencies and the innovative concept of phenomenon-based learning as integral to its new curriculum. This book highlights Finnish schooling and its education system, which consistently ranks among the best globally (Kangas & Rasi, 2021). Given the success of Finland's educational system, with its high rankings in international assessments like PISA, where it was in the top 5 in 2009, 2012, and 2015, policymakers worldwide began to study the PhBL methodology in depth (Grover, 2016). PhBL serves as an educational response to the ever-evolving challenges of the 21st century, requiring students and adults to acquire transferable skills and address current socio-economic issues.

The challenges of the 21st century differ significantly from those of previous eras, largely due to the rapid advancement of new technologies and the need for citizens, workers, and students to adapt to these changes. According to Finnish educational philosophy, the response to these challenges must involve a reformation of educational thinking and adaptability to change (Symeonidis & Schwartz, 2016).Although public discussions on Phenomenon-Based Learning (PhBL) often reference the National Curriculum for Basic Education, the term "phenomenon-based learning" is not explicitly mentioned in either the Finnish or Swedish versions of the curriculum (National Board of Education, 2014).

The process of exploration and discovery lies at the core of phenomenon-based learning, embodying the essence of science itself. This approach aligns closely with the philosophy underpinning the Next Generation Science Standards (NGSS). Instead of merely memorizing facts that may soon be forgotten, students actively participate in authentic scientific inquiry. They collaborate, communicate, and engage in critical thinking, gaining a deeper comprehension of scientific concepts and witnessing their real-world applications—exactly as envisioned by the NGSS. In essence, students are immersed in activities that mirror the practices of real scientists. Through exploration and discovery, they not only learn scientific principles but also embody the role of scientists themselves. (Bobrowsky, 2018)

2.2 PhBL and Real-World Issues – Engagement and Community

The multidimensionality of the curriculum design that includes PhBL as well as the aspiration to actively engage with the community and its real issues is also highlighted by the plurality of participants in the roundtables: policy makers, principals, experts from educational systems outside Finland and Europe, academics, teachers, stakeholders (Grover, 2016). A very important element of the community engagement of PhBL practice is that in the programming of this, in addition to the above, the students themselves are involved. More specifically, students are initially invited, through an exploration of their educational needs, to collaboratively set the learning objectives of each PhBL period with experts, teachers and stakeholders and to organise the educational programme based on real-life issues that they have to address through cross-learning techniques. Formulation and on behalf of the students is not a static condition at the beginning of the curriculum design, but a continuum in which students are invited to choose the PhBL study periods - each school chooses its own based on availability and preference -, to participate in the implementation of the interdisciplinary curriculum, to raise objections and changes if it no longer meets their needs, and finally to evaluate at the end of the learning period what they have learned or ultimately not learned (Strauss, 2015).

The purpose is to ensure that the learning objectives, understanding of multiliteracy and exploration of the phenomenon from different subjects are achieved. Exploration – searching for and analyzing information: Students search for and gather information about a selected phenomenon and critically assess (Kangas & Rasi, 2021).

The PhBL model highlights the importance of co-teaching between school and university educators, as well as fostering cross-curricular activities and subject interactions. The PLM model, serves as a practical tool for teachers to implement phenomenon-based multiliteracy learning. Its steps include teachers' collaborative design, student orientation sessions to establish shared learning visions, planning stages for students to select topics and research questions, checkpoints for joint evaluation of analysis plans, and exploration phases where students gather and critically assess information related to their chosen phenomena. These steps ensure alignment with curriculum objectives and promote students' engagement with multiliteracy through various learning methods.

2.3 PhBL and students reskilling and upskilling: Education 5.0.

The PhBL (Project-Based Learning) practice maximizes the reskilling and upskilling of learners. Upskilling involves upgrading the skills necessary for the present and future era. Reskilling refers to the ability to "learn how to learn again" and pertains to skills that students must be trained in a new way. Teaching with an emphasis on project-phenomena enhances skills initially related to Thinking and Learning to Learn, as well as Life Skills (Self-care and Managing Everyday life). PhBL aligns with contemporary educational needs by integrating real-life projects and phenomena into the curriculum fostering the development of problem-solving skills and a deeper understanding of learning processes.

The increasing necessity for interdisciplinary collaboration to address complex issues underscores the importance of equipping students with the skills to tackle these challenges. This study explored student reactions to interdisciplinary teaching within secondary agricultural education, highlighting considerations for teachers when implementing this approach. Generally, students responded positively to interdisciplinary teaching, influenced by various student characteristics. Key factors affecting their responses included the methods of facilitation and specific aspects of the interdisciplinary approach.

Student reactions reflected their level of interest in the topics, their acceptance of activity leaders, and their engagement with the educational methods. During focus group discussions, students consistently appreciated lectures, noting the clarity and understanding gained from them. Terms such as "explain," "presentation," and "understand" frequently described the value of lectures. Students particularly favored concise lecture formats, suggesting that 10-20 minute sessions were effective and should be more commonly used. Observations by the lead researcher corroborated this preference, noting the efficacy of shorter lectures. Regarding structure, focus group participants emphasized the importance of personal attention, overall guidance, and clear directions. They valued specific instructions, such as being directed to particular websites, and appreciated the individualized support provided by teachers as they moved among student groups. Students also noted the significance of connecting concepts, recognizing that tying everything back to the initial topic enhanced their understanding (Tsai et all., 2023).

In addition, through interaction with contemporary information, students are trained in interaction, self-expression, and acceptance of diversity, whether this pertains to cultural Competencies or Multiliteracy, a fundamental element of the PhBL practice. This method involving multicultural perspectives encourages collaboration and communication among peers, fostering self-expression and the ability to work effectively in diverse teams. As mentioned above, the ultimate goal of PhBL is to develop skills in students who will become future citizens-workers. Consequently, the curriculum focuses significantly on developing Working Life Skills. That means that projects simulate real-life working conditions focusing on problem-solving and brainstorming. The etrepreneurship skills are also as a goal to be served as the educational response to the Education 5.0 era. Students should tackle projects that require innovation and strategic planning gaining entrepreneurial skills like risk-taking and resource management and addressing real-world issues, promoting practical and applicable learning experiences. The Education 5.0 era envisions a learning environment where technology and human skills converge to create more personalized, effective educational experiences such as PhBL can combine human and machines skills through developing of human skills (versus machines skills) such as critical thinking and personal development mapping. This is about personalized Learning Paths that PhBL focus on through tailored projects to individual interests and abilities, making learning more relevant and engaging and making the student and the future citizen-employee ready to apply the learning outcomes in a personalized way and to be distinguished from machine learning chatbots and AI robots (Counsil for creative education (CCE).

At the end within the interdisciplinary approach, students were directed to various websites to gather data and subsequently made numerous connections with the concepts learned, referencing their world history and science classes. Research indicates that student characteristics significantly influence their reactions to interdisciplinary teaching. Teachers should consider these characteristics, particularly students' prior knowledge, when designing and implementing interdisciplinary approaches (Kennedy et all., 2020).

2.4 Integrating Phenomenon-Based and Model-Based Learning in Physics, STEM Education and Economics

The objective of physics education is to transition students from their everyday understandings and activities to scientific models and practices. This journey typically involves two distinct approaches: Phenomenon-based instruction and model-based instruction. Phenomenon-based instruction is characterized by subjectivity, emotional engagement, mediation, exploration, and limited use of models. Conversely, model-based instruction is defined by objectivity, logical reasoning, direct confrontation, hypothesis testing, and extensive utilization of models. Initially, it may appear that these two methods are incompatible. However, it is possible to integrate them to facilitate a gradual progression from phenomena to models in student learning. Five key criteria, based on expert opinions, delineate phenomenon-based instruction: subjectivity, emotional engagement, mediation, exploration, and restricted use of models. Subjectivity involves students gaining scientific insights through personal experiences, with teachers leveraging everyday experiences as the foundation for instruction. Classroom activities often entail immersive experiments where students actively participate, fostering an understanding of phenomena as interactions between the observer and the observed. Affectivity in physics instruction involves the teacher creating an emotional connection with the subject matter. By highlighting certain aspects of everyday phenomena, the teacher transforms them into engaging experiences resembling artistic presentations, inviting students to immerse themselves emotionally.

This approach fosters not only student interest and motivation but also emotional and social competencies by encouraging students to express their feelings openly. Mediation bridges the gap between students' everyday experiences and scientific concepts by using familiar phenomena as a foundation for learning. Through carefully planned steps, the teacher guides students from initial perceptions to deeper understanding, employing exploratory experiments and Socratic dialogue to facilitate learning.

Exploration involves hands-on experimentation, allowing students to familiarize themselves with the phenomenon in a lifeworld-oriented manner. By varying parameters and observing changes, students identify necessary conditions and develop empirical laws through inductive reasoning, which serve as the basis for predictions and further exploration. Over time, the teacher can transition students along a continuum, leading them from exploratory experiments to more theory-driven ones, from inductive reasoning to deductive reasoning, from descriptive modeling to explanatory modeling, and from their everyday experiences to the realm of physics. This approach allows for physics instruction to be both phenomenon-based and model-oriented. Certain elements of phenomenon-based instruction overlap with model-based methods, and vice versa. To effectively integrate all aspects, the teacher must adopt a flexible approach towards phenomena, teaching strategies, and models. give me a subtitle for this paragraph about PhBL (Grusche, 2019).

Let's explore an example of PhBL in physics, chemistry etc.

This study (Demirel & Coskun, 2010) aimed to explore the implementation of an interdisciplinary teaching approach, employing a case study design supported by a combination of qualitative and quantitative methods. Thirty-four 10th-grade students from a private school in Ankara were tasked with developing projects aligned with this interdisciplinary approach. To gauge the effectiveness of this approach, a pre-post test using a logical thinking skills test (GALT) was administered in a single-group experimental design format. To gather insights into the perceptions of students, teachers, and parents regarding the application of this approach, two sets of interviews were conducted before and after the implementation. Additionally, a questionnaire focusing on the interdisciplinary teaching approach was distributed to all teachers at the school.

In this research, a nested single case design, a type of case study design, was employed. This design allows for the examination of multiple sublayers or units within a single case, offering the opportunity for multiple units of analysis (Yıldırım and Şimşek, 2000). Data were collected from the school, with various sub-components analyzed. The students, teachers, and parents within the school organization were considered as sub-units, while the school organization itself served as the main unit of analysis. To complement the case study research, a quantitative study was conducted. The effectiveness of the interdisciplinary teaching approach, supported by project-based learning, was assessed using a scale (GALT) administered as both a pre-test and post-test. The study participants included 36 teachers working at a state high school in Ankara, along with 34 students and 29 parents.

Among the teachers, there were representatives from various subjects: 1 each from art, music, biology, chemistry, physics, geography, mathematics, computer science and

Among the teachers, there were representatives from various subjects: 1 each from art, music, biology, chemistry, physics, geography, mathematics, computer science, and psychology, and 2 each from history, literature, and English. In terms of parental education, 17 had attained a college degree, 10 held a high school diploma, and 2 had completed primary school.

Prior to the implementation, teachers underwent a comprehensive 6-hour training session on interdisciplinary teaching methods and project-based learning, led by researchers. The training encompassed theoretical concepts of project-based learning and showcased practical examples of interdisciplinary teaching applications, with 1 hour dedicated to approach introduction, 1 hour to studying application examples, and 4 hours to team collaboration. Teams comprising teachers from diverse subject areas were established beforehand, fostering collaboration across disciplines and ensuring close monitoring of the process.

The teaching-learning process strives to foster students' holistic understanding and interpretative abilities. It aims to equip them with skills to grasp problem statements, interpret data, formulate hypotheses, and engage in experiences that showcase their scientific and analytical reasoning. This process is deemed effective in developing skills such as proportional judgment, variable control, connective judgment, and relational judgment, all of which are assessed by the test of logical thinking skills.

Initially, students expressed that they did not actively utilize their existing knowledge to integrate new information, but they could recognize connections between closely related disciplines. By the end of the process, however, they reported consciously applying knowledge transfer, particularly linking historical topics with contemporary events. One student noted, "Every subject is interconnected, but recognizing those connections is crucial. I was particularly impressed when the teacher bridged math and history, which served as a model for me." Working across various disciplines and with different teachers throughout the process, and delving into specific research topics, empowered students to effectively transfer knowledge across diverse fields. The teaching-learning process endeavors to cultivate students' comprehensive comprehension and interpretive skills. Its goal is to provide them with the capacity to comprehend problem statements, interpret data, devise hypotheses, and partake in activities that demonstrate their scientific and analytical reasoning. This approach is considered efficacious in nurturing abilities such as proportional judgment, variable control, connective judgment, and relational judgment, all of which are evaluated through assessments of logical thinking skills.

Overall, interdisciplinary and phenomenon-based learning in secondary education have the potential to enhance student learning outcomes by promoting deeper understanding, critical thinking, and engagement with real-world issues. The development of a Pedagogical Learning Model (PLM) for phenomenon-based multiliteracy teaching is very important. The PLM model should emphasize representation diversity, co-teaching between school and university educators, cross-curricular activities, and collaborative student design. The model aims to support teachers in implementing phenomenon-based multiliteracy learning through collaborative design, student orientation, planning, checkpoints, and exploration stages.

What about PhBL and STEM?

STEM education is gaining significant traction across the five APAC countries, with some viewing it as a primary focus in ongoing educational reforms. While traditional education, emphasizing a mono-disciplinary approach, remains prevalent, an increasing number of educators recognize the importance of embracing an interdisciplinary approach. This approach aims to stimulate students to grasp overarching themes and concepts that transcend individual disciplines, establish connections between diverse fields, and expand their applicability to real-world scenarios, thus enabling them to redefine problems beyond conventional boundaries and devise solutions based on a fresh comprehension of complex situations. While traditional education, emphasizing a mono-disciplinary approach, remains prevalent, an increasing number of educators recognize the significance of embracing interdisciplinary methods. This approach aims to facilitate students' comprehension of overarching themes and concepts spanning multiple disciplines, fostering connections between diverse fields, and enhancing their ability to tackle real-world challenges by transcending conventional boundaries and devising solutions based on a nuanced understanding of complex situations. Undoubtedly, STEM education will continue to be advocated for and progress rapidly in these nations, with collaborative efforts from policymakers, educators, and other stakeholders. Furthermore, Vocational Education and Training (VET) may emerge as a pivotal conduit for delivering STEM education effectively. STEM teacher preparation programs vary widely in their approach to integration, reflecting differing perspectives on STEM as either monodisciplinary or transdisciplinary. In some countries, such as CA and HK, STEM is treated as distinct and separate subjects, with teachers specializing in individual fields without specific STEM qualifications or pre-service programs. Instead, they acquire STEM teaching skills primarily through in-service training or personal experience.

In contrast, in other contexts, STEM teachers receive comprehensive training in either intradisciplinary or transdisciplinary approaches, ensuring they are equipped to teach across STEM fields effectively. Initially, the conventional paradigm of segmented S.T.E.M. education predominates within schools, wherein discipline-specific curricula and instructional methods are favored (observed in CA, SG, TW, and the USA). Within this framework, schools may occasionally offer activities and modules that encourage students to merge the four STEM fields, although comprehensive integrative STEM courses are infrequent, particularly at the secondary and tertiary levels. Secondly, due to the entrenched nature of traditional education, which tends to prioritize individual STEM subjects, access to, flexibility in, and adequacy of integrative STEM education and curricula are limited, especially within formal educational settings (notably observed in CA, SG, TW, and the USA). The third challenge pertains to STEM teacher training and professional development. In many countries, teacher education traditionally concentrates on discipline-specific pedagogy, with most programs focusing on preparing educators within particular STEM disciplines, such as science or mathematics education. Consequently, educators often lack comprehensive competency in integrated STEM teaching methods, particularly at the secondary and tertiary levels. make it shorter (Ambroz, Pernaa, Haatainen, and Aksela, 2023).

Economic Phenomena in Phenomenon-Based Learning (PhBL)

Economic phenomena offer valuable real-world contexts for students to examine the complex functioning of economies and the societal impacts of financial events. The 2008 financial crisis presents a significant case for students to investigate within the Phenomenon-Based Learning (PhBL) framework. This investigation entails comprehending the crisis's causes, mechanisms, and effects, as well as understanding how economic policies and market dynamics influence economic stability or instability. Students can investigate specific aspects of the financial phenomena such as economic crisis through Inquiry-Based projects, Case Studies, Policy Analysis and Data-Driven Investigations (Heikkilä, 2022)

For example with a deep dive into the 2008 Financial Crisis students can investigate specific aspects of economic failures and social-economical phenomena, analyze the factors that lead to collapse of major financial institutions and evaluate the effectiveness of government interventions. Through a specific phenomenon students learn “on the job” what an economic crisis means, how economic-politic policies can be or not be effective and what is the role of social institutions and citizens. Especially students can use real economic data to study trends and impacts and make interdisciplinary connections linking the financial crisis to broader social and historical contexts.

Evaluating economic indicators such as (un)employment rates students can link

Evaluating economic indicators such as (un)employment rates students can link statistical and social indicators with economic crisis not only to understand the previous situation (crisis of 2008) but also to prepare interdisciplinary policies and methodologies that make them ready to navigate and address future economic challenges.

In addition, in PhBL students could use economic models to simulate the effects of different policy responses for other economic situations, such as a preparation of a conference with a concrete budget. Through the phenomenon of 2008 crisis students learn how to apply economic knowledge to all the aspects of their economic and social life enhancing their life skills. Finally, exploring the 2008 financial crisis through Phenomenon-Based Learning in social studies allows students to understand the complexities of economic phenomena and their broader societal impacts (Dullien et all, 2010)

2.5 PhBL and fun in school classes: Changing the rules in Europe and in USA. Phenomenon-based learning and model-based teaching

The traditional method of teaching science, which often involves the rote memorization of facts, has proven insufficient for fostering deep understanding and long-term retention among students. Decades of research suggest that conventional lectures—where students passively receive information—and standard lab activities focused on routine measurements and observations fail to promote substantial learning.

In contrast, Phenomenon-Based Learning (PhBL) provides a more effective and engaging approach that connects learning with enjoyment. PhBL starts with students observing a pertinent phenomenon, such as the phases of the Moon or a simple device. This initial observation stimulates inquiry and exploration, enabling students to directly interact with the phenomenon, akin to how scientists engage with their work through hands-on exploration and discovery. Adopting PhBL empowers educators to foster a vibrant and interactive learning setting. This approach not only boosts the engagement of science education but also enhances students' understanding and memory by immersing them in scientific inquiry. Prioritizing collaborative exploration and hands-on engagement with phenomena aligns with contemporary educational goals focused on developing critical thinking skills and instilling a deep respect for scientific methodologies. Each group of students is tasked with investigating the phenomenon as thoroughly as possible, a teaching method far away from teaching method with the teacher in the center, as the “learning magician”. This exploration involves hypothesizing, testing, and discussing observations, mirroring the scientific method. The goal is to encourage students to figure out the mechanics and implications of the phenomenon through active inquiry and enjoyment.

While the groups are engaged in investigating the phenomenon, you, as the teacher, should actively circulate among them. Your role includes monitoring conversations to ensure they are progressing scientifically. This involves asking probing questions and facilitating discussions on how to approach and address their inquiries, whether through experimenting with the gadget or through collaborative dialogue.

In today's classrooms, many students tend to wait passively for the teacher to simply provide answers. The goal here is for students to derive enjoyment from discovering the underlying principles independently, fostering creativity and innovation. The hands-on involvement encourages curiosity and critical thinking, as students seek to understand the underlying scientific principles and as researches show the students often listen more attentively to their peers than to their teachers, making group discussions a valuable part of the learning process. (Bobrowsky, 2018).

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In Finland, Mattila and Silander (2015) explore the concept of phenomenon-based teaching and learning within the realm of digital pedagogy. Silander (2015a) posits that real-world phenomena foster learning when studied holistically in their authentic context, integrating knowledge and skills across subject boundaries. Examples of such phenomena include climate change, the European Union, media and technology, and energy. Phenomenon-Based Learning (PhBL) involves observing authentic phenomena, using a systemic framework to understand the phenomenon, employing a metaphorical model to relate new information, creating a motivating foundation for learning (Silander, 2015a).

Silander (2015b) identifies five dimensions of PhBL: holisticity, authenticity, contextuality, problem-based inquiry, and the learning process. Depending on implementation, the approach can range from a basic study of phenomena to a comprehensive, multidisciplinary exploration of real-world issues. Authentic PhBL involves using real-world methods, tools, and environments, connecting learning directly to practical applications and involving experts to engage learners in professional practices and real-world problem-solving.This teaching mehtod is grounded in a problem-solving environment where the teacher initiates learning by posing questions or presenting problems. Students collaboratively develop answers to these questions or problems, focusing on phenomena that capture their interest (Silander, 2015a, p. 17). Instructional goals are collaboratively negotiated rather than imposed, and evaluation is used as a tool for self-reflection. This learner-centered approach connects theoretical learning to practical, real-world situations and phenomena.

To comprehensively study phenomena, team teaching involving various subject teachers is recommended as a key strategy (Silander, 2015b). In this approach, teachers act as facilitators, guiding and supporting students as they navigate problems identified by the students themselves, rather than merely transmitting facts. Teachers leverage their expertise to foster independent problem-solving and critical thinking (Silander, 2015b).

Käte Meyer-Drawe (2008) asserts that the concept of learning, which dates back to Aristotle and Plato, has been associated with various metaphors throughout history. She references Plato's allegory of the cave and Socrates' analogy of the educator's role to that of a midwife. Meyer-Drawe advocates for an experiential view of learning as the most pedagogically relevant, emphasizing the need to reclaim the concept of learning for educational thought and practice, rather than allowing it to be dominated by psychology or neuroscience. Learning, according to Meyer-Drawe, involves a transition where the old perspective fades and the new one has yet to fully emerge, creating a state of discomfort. She critiques modern views of learning that portray it as an effortless, enjoyable, brain-stimulating activity. Skeptical of the emphasis on autonomous and self-regulated learning (Meyer-Drawe, 2012), she argues that learning is always a process involving both the learner and the content, akin to awakening; it is both active and passive. Learning happens in such a way that we recognize it only retrospectively.

Educators inevitably perceive, act, analyze, and interpret things as something specific, reflecting the phenomenological notion that our attention is always directed and never neutral. Viewing students merely as autonomous creators of their own learning can constrain our understanding of their potential. Thus, it is crucial to consider both the content and the manner of the learning process, and to understand the dynamic interplay between teaching and learning. While students are integral to the learning process, they do not necessarily initiate it, and teachers cannot fully dictate it. Pedagogues and teachers operate within a normative framework that shapes their educational practices. Emphasizing the development of self-regulated learners can inadvertently result in students being blamed if educational efforts do not succeed. Learning is inherently directed towards something specific, for particular purposes, and involves interaction with someone else. From a phenomenological standpoint, learning as an experiential process means that students must undergo experiences rather than merely construct them. This process introduces elements of uncertainty and ambivalence, which educators must be ready to address and navigate (Symeonidis & Schwarz, 2016)

In a review (Tornetti et all.,2023) aimed to establish the current state of studies focusing on interdisciplinary experiences in schools, highlight the effects identified on both students and teachers, and identify the conditions conducive to the development of interdisciplinary sequences the findings about teachers are very interesting. The findings indicate that there is a scarcity of interdisciplinary practices in secondary schools, with even fewer achieving substantial integration. Many challenges contribute to this, including the limited availability of interdisciplinary training programs for teachers, who often lack the necessary preparation to support interdisciplinary teaching. Additionally, teachers must navigate their roles within interdisciplinary approaches and manage relationships with colleagues, while facing constraints imposed by institutional choices and opportunities. Despite these obstacles, interdisciplinary approaches demonstrate positive effects on both students and teachers, fostering learning, interest, relational competencies, and professional development. Furthermore, the review underscores the importance of certain conditions for constructing interdisciplinary practices in schools. However, ensuring high-quality integration is often challenging in practice, with projects typically tailored to their specific contexts and rarely categorized according to the level of integration achieved. Future research could explore the classroom effects of projects categorized as multidisciplinary, interdisciplinary, or transdisciplinary, providing valuable insights into their effectiveness.

A regard teachers' perceptions and understanding of interdisciplinarity in public secondary schools outside Europe, especially in Rio de Janeiro, Brazil the findings suggest a lack of institutional support and teacher competence in implementing interdisciplinary approaches in the classroom. Theis perceptions were analyzed alongside lesson plans prepared by those who claimed to have strong knowledge of interdisciplinary practices To address this gap, the study proposes the adoption of methodologies like Problem-Based Learning in teacher training programs in Brazil and emphasizes the importance of ongoing professional development through postgraduate programs. Upon analysis of the lesson plans, several observations were made. Only a few teachers explicitly outlined learning objectives and assessment procedures in their plans. Additionally, a small number of lesson plans involved collaboration among multiple teachers. Some plans lacked explicit descriptions of teaching strategies, while others relied heavily on traditional lecture formats. However, a few teachers incorporated project-based or problem-based approaches into their lesson plans (Fidalgo-Neto et all., 2014)

In a study carried out amongst teacher education students with the aim of enabling the effects of the aforementioned Interdisciplinary Educational Innovation Project to be evaluated, taking into account the development of the preservice teachers' skills. Interdisciplinary projects are pivotal in shaping students' profiles aligned with 21st-century skills. However, integrating an interdisciplinary approach poses challenges for both teachers and teacher educators. This study aims to devise an interdisciplinary model for teacher education and conduct an empirical investigation to assess its impact on learning

The descriptive statistics indicate that, for two dimensions of the principal variable (Teamwork and Interdisciplinary Teacher Education), the mean values across all groups surpass the midpoint of their respective scales. This suggests that, overall, preservice teachers perceive themselves as performing well in terms of teamwork and believe they have received adequate interdisciplinary teacher education. Furthermore, the main effect of the intersubject factor was statistically significant in three of the four dimensions of the principal variable: Teamwork Interdisciplinary teacher education and Assessment of a teacher's role as a manager of interdisciplinary activities Similarly, the main effect of the intrasubject factor was statistically significant in three dimensions of the principal variable: Knowledge Integration ($p < 0.01$), Interdisciplinary teacher education and Assessment of a teacher's role as a manager of interdisciplinary activities (Santa et all., 2020).

<u>2.6 PhBL and digitalization: Methodologies, Good Practices and App's examples</u>

In PhBL the digital tools play a significant role enhancing the learning outcomes and the blend of the curricula. Tools like Kahoot! using gamification and engagement make learning fun and effective for students. Students in the digital era keen to digitalization and not only can but want also the incorporation of digital practices into sciences. By incorporating elements such as quizzes, live competitions, and leaderboards, Kahoot! The educational content be transformed into a game-like experience that motivates students to participate actively and to gained knowledge and skills by doing, by phenomena (Cano,2023)

In addition, virtual reality and avatars are here. The integration of high-quality virtual tools alongside the traditional laboratory provides an enhancement of educational outcomes, in particular in terms of strengthening Life skills within the curricula. A case study worth noting is the case of engineering. In engineering education, many areas hybrid interactions integrate real and virtual laboratory experiences, making the transition to hybrid laboratory models that combine real and virtual laboratory experiences a reality forms.

Experiencing the changes of the post-pandemic AI era and subsequent needs analysis, the University of Agricultural Sciences and Veterinary Medicine (USAMV) in Bucharest launched the HybridPraxisLab in 2022, with the aim of developing a virtual laboratory for environmental engineering. This initiative is designed to create a virtual laboratory environment where students can conduct experiments aligned with environmental science curricula, specifically the “Pollutant Sources, Processes and Products". The project includes 28 hours of hands-on lessons in second semester of the 2022/2023 academic year, allowing students to apply theoretical knowledge through interactive, virtual experiments. This exploits PhBL as it combines engineering with other sciences in an “interactive blend”.

The HybridPraxisLab serves as an immersive learning platform that prepares students for real-world experimentation by providing virtual simulations of physical lab environments. This hybrid approach enables students to practice handling laboratory equipment and processes in a virtual setting, building confidence and competence before engaging in actual lab work. Such integration is crucial for bridging theory and practice, fostering engineering judgment, and illustrating process behavior through mathematical models and intuitive graphical interfaces. Ultimately, HybridPraxisLab aims to advance laboratory education by implementing innovative technical and pedagogical frameworks, enriching the learning experience through a seamless blend of virtual and physical lab interactions.

Another good example Phet. PhET Interactive Simulations, developed by the University of Colorado Boulder that represent a powerful educational resource that enhances science and mathematics education through engaging, interactive, and accessible tools. They support various teaching methodologies, align with educational standards, and provide a versatile platform for exploring complex concepts. While not a replacement for physical experimentation, PhET simulations complement traditional lab activities and offer significant advantages in terms of accessibility, engagement, and conceptual understanding. As educational institutions continue to integrate digital tools into their curricula, PhET simulations stand out as a valuable asset in modernizing and enriching the learning experience. The Phet especially offers a comprehensive suite of web-based tools designed to enhance science and mathematics education through engaging, interactive simulations. The platform provides numerous educational advantages, transforming traditional learning paradigms and addressing various pedagogical needs across different educational levels by using a user-friendly interface that is intuitive and accessible, even for younger students or those with limited technological skills. The drag-and-drop functionality, adjustable parameters, and immediate visual feedback make the PhbL teaching interactive and easier.

PhET simulations support Inquiry-Based Learning and they are particularly effective in supporting inquiry-based learning, a pedagogical approach where students learn by asking questions, conducting investigations, and constructing knowledge. By providing a safe and flexible environment for experimentation, PhET simulations allow students to test hypotheses, explore outcomes, and engage in scientific reasoning, mirroring the processes used in real scientific inquiry. Educators can assign specific simulations or tasks based on students' proficiency levels and experiences.

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Chapter 3: Case Studies from Selected European Countries

Abstract

This chapter explores the practices, opportunities, and challenges of interdisciplinarity in secondary education, drawing from both primary and secondary data. A key case study is the Liceo Ginnasio Statale Virgilio in Rome, which launched the ATLAS project to blend humanistic and scientific studies through an interdisciplinary approach. The study examines how merging subjects like art and science through STEAM education enhances student engagement and collaboration. Based on roundtables and video podcasts with stakeholders from Cyprus, Italy, and Greece, the chapter provides practical guidelines for integrating interdisciplinarity, including selecting real-world phenomena, developing inquiry questions, and fostering problem-solving skills. Successful implementation requires gradual integration, clear objectives, and openness to feedback from students, ultimately preparing learners to navigate complex global challenges.

Introduction

This chapter introduces some practices, opportunities and threats of interdisciplinarity in secondary schools through a collection of secondary data, in particular with reference to some case studies, and primary data, considering a case study and some listening activities carried out in Cyprus, Greece and Italy through video podcasts and round tables.

3.1.1 Presenting the selected case studies

The case studies analysed vary by countries, research methodology and educational experiences (i.e. Interdisciplinarity and/or PhenoBL). For this reason, it is useful to carry out a descriptive analysis before delving into the main results.

The first case study presented is a country case study: Finland. This country has been elected because interdisciplinary approaches have played a significant role in its educational and policy-making landscape. Moreover, Finland has been recognized for its innovative and successful educational system, which emphasises equity, cooperation, and interdisciplinary learning based on twenty-first-century skills (Braskén et al., 2020; Üstün & Eryilmaz, 2018). The Finnish curriculum's learning objectives are centred around competencies in thinking, learning-to-learn, cultural understanding, communication technology, and entrepreneurship to construct a sustainable future (FNBE, 2016).

The importance of integration among different subjects has been addressed in the Finnish national curriculum for several decades[1], but currently, the FNBE (2016) states that all schools The importance of integration among different subjects has been addressed in the Finnish national curriculum for several decades[1], but currently, the FNBE (2016) states that all schools must design and provide at least one "multidisciplinary learning module" per year for all students, focused on studying phenomena or topics that are of special interest to students. Moreover, students are expected to participate in the planning process of these studies, and the phenomena being studied should allow every student to work with questions that interest them (Braskén et al., 2020).

Additionally, in the interdisciplinary approaches that Finland implements in its curricula, it follows the methodology of Phenomenon-based learning (PhenoBL) which is a progressive approach to curriculum and pedagogy suitable for 21 st Century learners.

[1] The incorporation of interdisciplinary methodologies in education in Finland was initiated in the 1960s with the introduction of the comprehensive school system (CPI, 2019). Although the government had begun contemplating changes to the education system as early as 1945, it was not until the 1960s that the comprehensive school system was established. After WWII, Finland saw significant changes in its population and economy. The demand for high-quality education also increased, resulting in more students enrolling in grammar schools. However, there were inequalities as children from agricultural and working-class backgrounds attended grammar schools in low numbers. Similarly, there was a stark urban-rural divide. This led to the need for reforms to provide quality education for all children regardless of their socioeconomic background or where they lived (CPI, 2019) . All of that resulted in the transformation of the Finnish education system gained recognition in the early 2000s when Finnish students began to score exceptionally well in international assessments such as the Programme for International Student Assessment (PISA; CPI,2019).

A field investigation has been conducted in Italy through detailed interviews. The case study outlined is that of the Liceo Ginnasio Statale Virgilio[1] in Rome. Since 2017, the school has been involved in a renewal of its teaching methodology and to this end has created a particular pathway called ATLAS[2] (Art - Translation - Laboratory - Knowledge), with a multi and interdisciplinary educational approach, aimed at merging humanistic studies and science through the study of classical culture. The project aims to place students at the centre of the learning process by making them active participants through collaborative activity experiences and workshops.

The methodology provides for an inclusive teaching plan of co-teaching moments, during which the study of Art History, starting in the first year, is supported by teachers of History, Mathematics, Physics and Philosophy, with a view to experimenting with a plural and problematising approach, which is a method in line with the most recent academic orientations. Students are also offered the optional opportunity to stay at school for a few hours per week during which they can ask a teacher of their subject area for study support, if necessary.

The case study focuses on a particular section of the classical address called ATLAS created in 2017 with the intention of merging the humanistic studies and science through the study of classical culture. Interdisciplinarity is the project's distinctive feature; students are offered co-participation teaching hours where themes related to art, myth and history are tackled from different perspectives, fostering in the class the development of a deep-rooted critical sense and harmonious learning.

The project, which has almost begun as a bet thanks to a few teachers sensitive to the physiological changes that teaching undergoes with the passage of time[4], is today one of the school's strengths, as it is capable of attracting students who, driven by curiosity towards innovation, enthusiastically face the challenges of a stimulating course that places them at the centre of the phenomenon, making them an active part of learning. It is an example of a situation where the focus has shifted from what to teach to how to teach it.

[2] The Liceo Ginnasio Statale Virgilio has been for over fifty years a reality in the Roman secondary education scene in continuous movement and evolution. It is located in Via Giulia, right in the historic centre, housed in a building built in the late 1930s by architect Marcello Piacentini, to which the seventeenth-century Ghislieri College and the Church of the Holy Spirit of the Neapolitans are annexed. The school currently accommodates approximately 1050 students, divided into 46 classes, with an average of 22 students per class. In its educational offer it is possible to choose between: Liceo Classico, Liceo Scientifico, Liceo Linguistico, Liceo Linguistico Internazionale Spagnolo, Liceo Linguistico Internazionale Francese.

[3] ATLAS is a new track of the traditional Liceo Classico based on an educational and methodological innovation that includes the study of art history starting from the first year instead of the third.

[4]The need for methodological innovation arose in 2017 from the realisation that, in more or less regular cycles, the classical high school is experiencing a downturn.

Considering Turkey, the case study is extrapolated from a study of Demirel & Coskun (2010) which aimed to explore the implementation of an interdisciplinary teaching approach, employing a case study design supported by a combination of qualitative and quantitative methods. Thirty-four 10th-grade students from a private school in Ankara were tasked with developing projects aligned with this interdisciplinary approach. To gauge the effectiveness of this approach, a pre-post test using a logical thinking skills test (GALT) was administered in a single-group experimental design format. To gather insights into the perceptions of students, teachers, and parents regarding the application of this approach, two sets of interviews were conducted before and after the implementation. Additionally, a questionnaire focused on the interdisciplinary teaching approach was distributed to all teachers at the school.

Data were collected from the school, with various sub-components analysed. The students, teachers, and parents within the school organisation were considered as sub-units, while the school organisation itself served as the main unit of analysis. To complement the case study research, a quantitative study was conducted. The effectiveness of the interdisciplinary teaching approach, supported by project-based learning, was assessed using a scale (GALT) administered as both a pre-test and post-test. The study participants consisted of 36 teachers working at a state high school in Ankara, 34 students and 29 parents. Among the teachers, there were representatives from various subjects: 1 each from Art, Music, Biology, Chemistry, Physics, Geography, Mathematics, Computer Science, and Psychology, and 2 each from History, Literature, and English. In terms of parental education, 17 had attained a college degree, 10 held a high school diploma, and 2 had completed primary school.

An open-ended interview format was employed to conduct interviews with participants. To gather insights from both students and teachers regarding the process, four teachers and ten students who participated in the application were interviewed using the focus group interview technique before and after the application. Each teacher was presented with six open-ended questions, while the same set of questions was utilised for the student interviews. Parents' perspectives were gathered through a questionnaire consisting of eight open-ended questions. Expert opinions were sought to ensure the content validity of the interview forms.

In fact, in recent years, many schools of classical studies have experienced a decline in enrolments, due to the undeniably greater interest in scientific subjects than in the humanities. Teachers and headmasters therefore reflected on the trend in their enrolments and, based on the data, opted to set up a commission to consider what they could do to change the educational offer and make the study of classical subjects more appealing. The response was the birth of the experimental ATLAS section, where interdisciplinarity and laboratory experiences join forces to meet the needs of students who are increasingly attentive to the practical aspects of learning at school desks.

Considering Norway and Denmark, the case study is extrapolated from a study of Termaat (2023) which examines the operational perspectives and practices of teachers with direct experience implementing interdisciplinary units in five small schools. These are 4 schools in Norway and 1 in Denmark, which implement English-medium Middle Years Programme (MYP) friskoler. In these schools, teachers develop 'unique school-based interdisciplinary units'. Quantitative survey data were collected by 36 teachers and qualitative data were collected from 9 of those teachers, who represented 3 Norwegian schools.

3.1.2 Educators, students and policymaker: experiences and challenges

What experiences and challenges can we summarise from these case studies?

Considering the experiences, for example in Italy, the application of ATLAS translates into the addition of one hour to the canonical 27 weekly hours total planned for the first two years of the five-year course. During these hours, the classes deal with themes of classical art history through a didactic approach conducted in collaboration with teachers of Geography and History, Greek and Latin, with targeted in-depth sessions (focus) capable of immersing the students in a detailed dimension of the historical and cultural contexts of the individual works and monuments studied, in favour of a greater extensiveness of knowledge awareness. The entire project aims to approach classical art topics with greater calm and a critical attitude, so as to lighten part of the syllabus for the following three-year period and to enable the topics to be aligned with those in the syllabus for the subjects of Geography, History and Classical Literature.

More time allows them to experience both learning and teaching in a more relaxed atmosphere, and it becomes possible to increase the number of class outings to one per month. Students not only study Art from an academic point of view, but also have the opportunity to experience it first-hand by visiting museums and archaeological parks, where they are involved in the promotion and management of culture, developing their problem solving and cooperation skills.

Classroom work is complemented by a study-assistance afternoon programme, where students have the opportunity to stay in school for two hours a week and ask for clarification or practice with teachers of Latin and Greek subjects. The variety of viewpoints offered and the workshop-like atmosphere of the activity help students strengthen their critical sense as well as the awareness of their own abilities.

Results has shown that:

- co-presence has made teaching fun and productive;
- the students benefit from exposure to multiple and multidisciplinary points of view, as it helps them to overcome the gap between the scientific and humanistic aspects of knowledge, but also to break out of the pattern of a rigid perspective;
- the transition to the next three years is smoother; the students arrive more prepared and aware of what they have learnt, with a solid foundation in classical art history, Latin and Greek more in line with the history and philosophy syllabus they will face. Working with trained minds means, for the teachers, being able to take the freedom to change the cards on the table and mix up the topics of the syllabus without the fear of leaving any element of the class behind;
- the interdisciplinary approach favours the learning experience of students with specific learning disorders;
- at the end of the five years, the students develop such a mastery of the topics covered that they report feeling like specialists in the field. This contributes to giving their work a sense of quality.

The Turkey case study is interesting considering the antecedent activities due to implement the project. In fact, prior to the implementation, teachers underwent a comprehensive 6-hour training session on interdisciplinary teaching methods and project-based learning, led by researchers. The training encompassed theoretical concepts of project-based learning and showcased practical examples of interdisciplinary teaching applications, with 1 hour dedicated to approach introduction, 1 hour to studying application examples, and 4 hours to team collaboration. Teams comprising teachers from diverse subject areas were established beforehand, fostering collaboration across disciplines and ensuring close monitoring the process.

Moreover, both the beginning and conclusion of the process involved seeking input from participating teachers to incorporate their perspectives. Meanwhile, students in the research group received a 2-week (12-hour) instruction on scientific research techniques and project preparation based on interdisciplinary teaching. Their proficiency in utilising internet, computer, and PowerPoint tools for project work was assessed through information forms, with deficiencies addressed accordingly. Additionally, a 4-hour presentation was provided to students on research conduct and project preparation before they selected project topics and formed groups of 2-3 members. Each group was assigned a teacher as an advisor, who reviewed and confirmed project topics for suitability. Teachers from various disciplines allocated working hours according to the projects; requirements and provided guidance tailored to their areas of expertise. “Logical Thinking Group Test” was applied to the students at the beginning and end of the process.

The selected Turkish teaching-learning process strives to foster students' holistic understanding and interpretative abilities. It aims to equip them with skills to grasp problem statements, interpret data, formulate hypotheses, and engage in experiences that showcase their scientific and analytical reasoning. This process is deemed effective in developing skills such as proportional judgement, variable control, connective judgement, and relational judgement, all of which are assessed by the test of logical thinking skills. Initially, students expressed that they did not actively utilise their existing knowledge to integrate new information, but they could recognize connections between closely related disciplines. By the end of the process, however, they reported consciously applying knowledge transfer, particularly linking historical topics with contemporary events. One student noted "*Every subject is interconnected, but recognizing those connections is crucial. I was particularly impressed when the teacher bridged maths and history, which served as a model for me*". Working across various disciplines and with different teachers throughout the process, and delving into specific research topics, empowered students to effectively transfer knowledge across diverse fields. The teaching-learning process endeavours to cultivate students' comprehensive comprehension and interpretive skills. Its goal is to provide them with the capacity to comprehend problem statements, interpret data, devise hypotheses, and partake in activities that demonstrate their scientific and analytical reasoning. This approach is considered efficacious in nurturing abilities such as proportional judgement, variable control, connective judgement, and relational judgement, all of which are evaluated through assessments of logical thinking skills.

At the beginning of the process the teachers pointed out that the level of students' perception was insufficient in establishing associations between topics learnt, and that it would be difficult to instil the skill in students in secondary education. They highlighted the importance of designing effective learning activities and equipping students with the ability to analyse and interpret knowledge proficiently. Regarding the skill of effective language usage (self-expression), teachers initially noted the influence of families and communities on language skills and their efforts to cultivate this skill in students. By the end of the process, they stressed the necessity of closely monitoring students' interests to facilitate the development of these skills, emphasising the integration of such skills into the objectives of all courses. A considerable portion of teachers were found to lack proficiency in utilising evaluation methods aligned with the interdisciplinary teaching approach. Approximately 58% of teachers reported not conducting evaluations beyond traditional exams, and 64% admitted to not being able to assess learning processes comprehensively. Additionally, 50% of teachers indicated not facilitating student self-assessment, while 56% reported difficulties evaluating learning outcomes applicable to real-life scenarios.

The Norway case study's experiences defined other interesting experiences. From the educators point of view:

- teachers were overwhelmingly positive designing meaningful units of interdisciplinary work;
- small schools are advantaged in the opportunities they provide for spontaneous communication between specialist teachers;
- effective collaboration required more time than schools provided;
- adjustments were necessary for each student cohort, new colleagues, and throughout implementation. Adjustments required constant dialogue and collaboration;
- interdisciplinary and disciplinary assessment is qualitatively different. Marking of interdisciplinary products involves both (all) teachers involved in the IDU;
- keeping detailed documentation was viewed as necessary, bureaucratic and time consuming.

From the student's point of view:

- learning to identify connections and synergies between disciplines prepared students for their MYP Personal Project (completed in MYP 5), the Diploma Programme, and future, innovative careers.
- bridging disciplinary content using conceptual connections helped students develop abstract thinking.
- students were more open to learning during formative stages of projects. Freedom of expression was controlled within parameters of narrow frameworks or firm boundaries.

In the end, the Norway case study can make policymakers reflect on some issues:

- smaller schools "are uniquely enabled to offset some of the complexities of interdisciplinary practices that frustrate larger schools";
- small school should allocate adequate collaborative planning time and organise teaching schedules, interdisciplinary subject linkages, pair teachers in shared workspaces and offer teachers greater flexibility to attend staff meetings;
- in each year cohort, common non-teaching periods needed to be prioritised for teachers implementing interdisciplinary units in small schools;
- shared physical space and online platforms provided opportunities for informal and formal meetings. Assessment and moderation were best completed together;
- release teachers participating in interdisciplinary units from formal meetings during peak implementation times (e.g., moderation of student work).

Regarding PhenoBL experiences in Finland, it is an innovative instructional approach that emphasises inquiry-based learning and holistic understanding, and it is rooted in the 2016 national curriculum reform. The primary objective of PhenoBL is to engage students in real-world phenomena exploration, thereby fostering critical thinking, creativity, teamwork, and communication skills. PhenoBL revolves around the natural curiosity of students, and it allows them to investigate and solve problems related to interdisciplinary issues. For instance, The English School in Helsinki organised a phenomenon-learning week where students from various grades approached the concept from diverse angles. They created projects guided by their inquiries, which exemplified the PhenoBL approach. Inquiry-driven and sustained by 21st-century skills, PhenoBL encourages students to pose essential questions, conduct research, and explore multiple perspectives on a phenomenon. The process goes beyond memorising facts; it involves evaluating sources, interpreting information, and using evidence to develop new understandings. The resulting projects, ranging from digital posters to 3D models, serve as a culmination of students' learning and a means to share their newfound knowledge with an audience. PhenoBL not only benefits students but also promotes teacher collaboration and interdisciplinary projects, such as combining art and physics or biology and cooking. The approach also allows students to explore and create using high-tech tools like virtual reality and 3D design programs. Furthermore, PhenoBL instils a sense of advocacy in students. For instance, a seventh-grade class researching water usage in their community presented data through graphs, utilised LEGO robots to address water-related challenges, and proposed solutions. The project empowers students to take action based on their discoveries. In essence, PhenoBL's success lies in engaging students in the process of inquiry, fostering curiosity, and challenging them to pursue their dreams. By intertwining real-world phenomena with education, Finland's instructional model encourages students to go beyond traditional learning and illuminate what they once considered mysteries.

PhenoBL and Interdisciplinarity are innovative pedagogical approaches that encourage learners and educators to surpass the constraints of traditional subject teaching and delve into interdisciplinary explorations and diverse phenomena. In Finland, one of the major strategies to implement Interdisciplinarity in the curriculum was to provide all students with an opportunity to explore issues that genuinely interested them (Braskén et al., 2020). By doing so, students were empowered to take charge of their learning, develop an inquisitive mindset, and enhance their critical thinking skills through inquiry-based learning. This approach is particularly beneficial for businesses and academic settings as it fosters creativity, collaboration, and problem-solving skills, which are essential for success in the 21st century.

Considering the **challenges**, in the Norway case study, one challenge was teachers' workload in developing the interdisciplinary units. On average, teachers spent over 17 hours "*to design and evaluate an interdisciplinary unit*" and a further 7 hours were required "*to assess and moderate student reflections*".' This was in contrast to the 3 hours allocated by the schools for collaborative task planning. These administrative demands of implementing interdisciplinary education were not recognized by schools, as teachers had to find time themselves for the meetings. Moreover, although reflection supported interdisciplinary learning, it was time consuming, and for younger students, overly bureaucratic.

In Italy, although teaching with a workshop and interdisciplinary focus arouses a great deal of enthusiasm, it also meets with some resistance among both students and teachers, who sometimes find it difficult to deviate from the classical approach of their own curricula and react rigidly to the need to merge with the requirements of their colleagues in other subjects. On the other hand, one of the stumbling blocks that an interview with the art history teachers of the ATLAS sections revealed is the undeniable complexity of the nomenclature that first-year boys and girls have to master in order to be able to deal with classical art topics. In some cases, it is still difficult to prevent the playful spirit from transforming the teaching hours carried out in co-presence into moments of play. In conclusion, it was found that in the aftermath of the Covid-19 pandemic, it became difficult for some students to feel comfortable in workshops and sharing contexts. However, teachers report that the trend is improving exponentially. Finally, the most critical issue appears to be the difficulty in managing the students' class time during the days when the art history teachers are busy with the students of the sections on educational outings.

In Finland, despite its potential to enrich the learning experience, PhenoBL presents certain challenges that cannot be overlooked. In this regard, Lähdemäki (2018) has pointed out that both educators and learners face difficulties in the process of transitioning from the identification of a phenomenon to the development of an interdisciplinary unit of inquiry that is feasible to execute. The teacher's primary responsibility is to assist students in identifying a problem that is sufficiently complex to be explored from multiple disciplinary perspectives, while at the same time being manageable enough to be tackled comprehensively. When implementing a PhenoBL approach in the classroom, both students and teachers must decide on a phenomenon for analysis through mutual agreement. Sam Tissington (2019) advocates the use of current events and local issues as springboards for this process. Jenna Lähdemäki (2018), in a similar vein, suggests allowing students in Year 8 to select a phenomenon related to Europe. In this example, the students chose Auschwitz, Food Culture in Germany, and European Art as their phenomena. Once a phenomenon has been identified, educators must use problem-based and inquiry-based pedagogies to conduct their investigations (Halinen, 2018; Lähdemäki, 2018).

Problem-based learning involves posing a problem to the class that can be solved through active learning, while inquiry-based learning requires the use of systematic methods to address a problem. In a PhenoBL approach, teachers may need to structure lessons that require students to explore multiple subject areas. Symeonidis and Schwartz (2016) suggest that it may be beneficial for educators with different subject-specific expertise to collaborate, thereby promoting a cross-curricular focus during investigations.

3.2. Listening to stakeholders in Cyprus, Greece and Italy.

As part of the project, partners did three video podcasts and four roundtable discussions with stakeholders from Cyprus, Italy and Greece. The main finding from these listening activities can be summarised as follows.

3.2.1 Cyprus & Greece

Lack of interdisciplinarity in the official secondary education curriculum is a significant obstacle. Stakeholders highlighted the "wall" of the curriculum, which is subject to considerable time constraints, as a primary challenge. They all agreed that the current curriculum lacks the character of interdisciplinarity and needs to be revised to incorporate more interdisciplinary approaches.

Lack of time. The primary concern that emerged from stakeholders deliberations was the time constraints imposed by the official curricula on teachers and, consequently, on students.

Interdisciplinary approach is widespread in Greece, especially in applied sciences as well as theoretical courses. For example, in the gymnasium there is the so-called “skills lab”, where students have to combine several disciplines from science, technology, mathematics, in order to achieve specific tasks.

Bottom-up boost to transition to an interdisciplinary curriculum is necessary. Stakeholders proposed that the change should come from both teachers/educators to public officials.

Top-down approach to transition to an interdisciplinary curriculum is also necessary. In fact, stakeholders suggested that a unified framework for assessing and approaching student learning is needed, ensuring that all disciplines contribute equally to the learning process.

Planning is the best approach. Every lesson could have an interdisciplinary approach if well planned. Starting from listening to the professors, policy makers will have to search the specific curriculums of the courses in order to see where interdisciplinarity could be applied.

Training programmes for educators are important and can be opportunities for their professional development. For instance, one of the stakeholders participated as a trainer in an educators' training programme that Greek and Cypriot secondary educators took part in. The Greek educators received ECTs that they could utilise in their future endeavours, such as seeking a promotion. Furthermore, the initiative attracted the voluntary participation of Cypriot teachers. The aforementioned opportunity can be realised in a multitude of projects and initiatives that promote interdisciplinarity. This can prove beneficial for their training, thereby enhancing their interest in participating in such training programmes, particularly outside of normal working hours.

Starting from etymology. A stakeholder posited that a significant proportion of terms can be found in multiple disciplines. Consequently, the school curricula should be based on an interdisciplinary approach, with examples including "calculus" and "speed".

Use of technology is enhancing interdisciplinary skills. Professors use new educational technologies, including computers and several software pieces, as well as emulation and simulation software. It helps very much both in the aspects of interdisciplinarity and phenomenon-based learning. Many software tools are available. An example is the software tools involving simulation and emulation.

3.2.2. Italy

Learning by Doing methodology in STEAM. The disciplines studied with an interdisciplinary approach are mainly science disciplines. An 'A' for “Art” has been added to the STEM (Science, Technology, Engineering and Mathematics) programme: STEAM. It was precisely this addition that was designed with the intention of uniting science subjects with art, which then translated into further disciplines in Italy.

Co-presence in the classroom focusing on a common objective is the main strategy. For example, often the history professor collaborates with the art professor. All the interdisciplinary programmes are decided at the beginning of the year, like most of the educational outings.

Time and space organisation is fundamental. More planning activities are needed among colleagues for an interdisciplinary approach, in terms of content but also in terms of approaches. Unfortunately, nowadays this is left to the voluntariness of the teachers. More investments are needed.

Collegiality and prosociality as a keyword. Education is a collective experience: a group of students versus a group of teachers. Nowadays, unfortunately, Italian training focuses on the notions of the individual teacher and not on a path of collective experience as it was until a few years ago.

Technology is at the heart of the interdisciplinary approach. But some technologies are still completely invisible in Italian schools, for example virtual reality.

Engaging students with a connection with real life to capture their attention. Students are tired of absorbing notions from a sitting professor: they want to talk, debate, express their opinions and delve into what interests them. The school can involve them by organising educational trips based on what they learn at school.

Students are demanding a change in the teaching approach. They have been clamouring for this for some years, for example last students' strikes were for asking for a change in the teaching approach. They no longer want to be evaluated with a grade, looking at what happens in Europe, where grades are disappearing using broader assessments that evaluate behaviour and acquired skills.

The assessment moment would change from the traditional one to a new one. Due to the interdisciplinary nature of the concepts approached from several perspectives, educators should try to assess more the participation and the acquisition of wide-ranging competences. But the traditional assessment must still be used for non-interdisciplinary moments, following the rules.

Families are not yet actively involved in the multidisciplinary approach. Actually, their role is limited: they are not involved or are rarely involved. But it is an interesting point: for example, some parents can contribute with additional knowledge.

3.3. Practical Implementation Guidelines, Methodologies and Best practices for secondary educators.

From the study conducted, it is possible to deduce some good practices to propose to secondary school educators so that interdisciplinarity can bring benefits to the students' learning experience. Here are some guidelines to take into account to facilitate the process of methodological integration.

- Have learners choose a “phenomena” from the real world; the topic should have a global context and be related to real life issues or events;
- Develop an inquiry question around this topic that begins with either “how”, “why” or “what if?”;
- Identify and teach the basic concepts that pertain to the learner’s chosen question; what skills or knowledge do they need to solve the problem?;
- Ensure that there is an open time structure for learners to engage in the necessary research and problem solving;
- Set up a framework that will guide students through the process and develop their own way of solving it.

Interdisciplinarity can become a valuable tool for secondary school educators, but in order to avoid the risk it becomes an additional element of complexity, it is essential that the approach to it is gradual and based on solid objectives: having a clear path allows one not to give in to the first resistance that any change can generate.

Let the educator therefore be patient, flexible and open to receiving feedback and criticism from the only real actors in the educational context: their students. Interdisciplinarity can make a difference in forming a new class of workers who are more aware of and ready to face the multifaceted nature of today's cultural context; but this can only be achieved if the educators of today and yesterday are ready to put themselves on the line to become the educators of tomorrow.

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Chapter 4: State of European Education Systems and Prospects for Interdisciplinary Adoption

Abstract

This chapter examines the growing interest in Phenomenon-Based Learning (PhenoBL) across European countries, highlighting its benefits in enhancing student achievement, fostering interest in science, and improving overall learning outcomes. Despite these advantages, PhenoBL is not yet widely implemented in secondary education, partly due to the lack of teacher preparation and the rigidity of traditional educational systems. The compendium seeks to equip EU secondary school teachers with knowledge of PhenoBL and interdisciplinary approaches by reviewing educational practices in partner countries—Italy, Greece, and Cyprus—and drawing on successful examples from Nordic countries.

The chapter discusses the challenges posed by the common core curriculum, such as a lack of critical thinking development, individualization, and adaptation to new educational trends. It also presents the Single Structure Education model used in the highest-rated PISA countries, where interdisciplinarity plays a crucial role in fostering problem-solving and innovation.

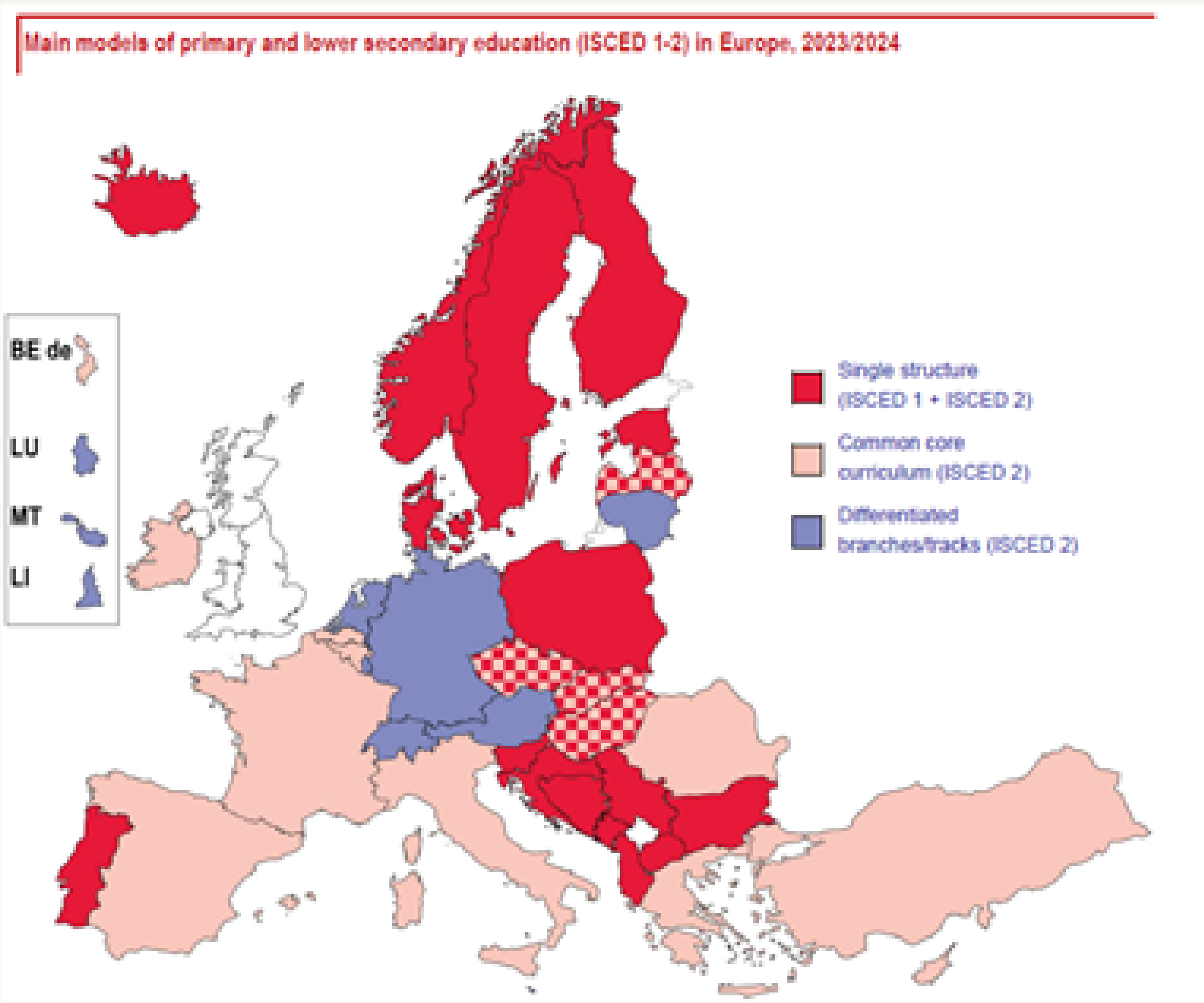
Introduction

Phenomenon-based learning (hereinafter PhenoBL) is a subject of considerable interest in the majority of European countries. This is due to the fact that research data indicates that PhenoBL is more successful in providing effective learning, better student achievement, a stronger interest in science, and even a higher happiness index (Ciuciulkiene et al., 2023). The success of the PhenoBL method is greatly influenced by the preparation of teachers (Ciuciulkiene et al., 2023) and despite the numerous advantages of PhenoBL, it is not commonly employed in European secondary education and within all the contexts of national. Therefore, this compendium aims to equip EU secondary school teachers with knowledge of the interdisciplinary approaches offered by PhenoBL.

4.1 Overview of European education systems

Before looking at the actual application of PhenoBL, we will explore the current state of education systems across the EU and in particular in the partner countries Italy, Greece and Cyprus, as well as outline some good practices from other EU countries. The three countries in the consortium have a common core curriculum, which means that after successfully completing primary education (ISCED level 1), all students move on to lower secondary education (ISCED level 2), where they follow the same general common core curriculum. This kind of education though faces challenges despite the fact that it aims for consistency and standardization. First, it lacks individualisation and does not cater for different learning styles and needs. Second, its rigidity can hinder adaptation to evolving educational trends and societal changes. Third, a homogenised educational experience can stifle creativity and unique perspectives. Fourth, teachers may have limited autonomy to adapt their methods. Finally, the emphasis on standardised testing can place undue pressure on both students and teachers.

The division of the educational systems within European context is the following:



Source (European Education and Culture Executive Agency -European Commission, 2023)

Therefore, the most influential and impactful school systems follow a common core curriculum. A significant shortcoming of the common core curriculum, as identified by 60% of employers who participated in the research, is its lack of emphasis on critical thinking development (TEDx Talks, 2019). Critical thinking is a crucial 21st century skill that is needed in order to

It is not included in the official national curricula. Often, disciplines are approached through a single-theme approach, as discussed in the podcast series and the roundtable discussion findings.

The countries with the highest rates in PISA ratings in terms of education offer a Single Structured education. Single Structure Education refers to an educational approach that integrates different disciplines and subjects into a unified framework (Miller, 2010). In the Nordic countries, interdisciplinarity plays a crucial role, especially in higher education. Interdisciplinarity involves solving complex problems and answering questions that cannot be adequately addressed by single methods or approaches (Achille & Fiorillo, 2022). It goes beyond the mere juxtaposition of disciplines and aims at a deeper integration. Scientists and educators recognise that societal challenges require collaborative efforts across traditional boundaries. By fostering interaction, synthesis and shared conceptual frameworks, the Nordic countries promote innovative knowledge creation.

4.2 Challenges and opportunities related to adopting interdisciplinary approaches.

Consequently, interdisciplinary approaches in education, such as PhenoBL, are of paramount importance for a multitude of reasons that affect students' academic performance and teachers' overall well-being and professional development. Many of the educators who participated in the previous activities, namely podcasts and roundtable discussions, elaborated on the issues that a mono-disciplinary approach has on them, as they are under excessive pressure to cover everything that is required. Apart from the time constraints that were discussed during the roundtable discussions and podcasts, another challenge that was identified in terms of applying PhenoBL is the teacher’s professional preparation for the effective implementation of this approach (Ciuciulkiene et al., 2023). To achieve the best possible outcome of PhenoBL, Finland imposed an educational reform in 2014 -that was implemented in 2016- and included in the national curricula PhenoBL with a basic moto that “the what and why” of learning into one simple “how”(Ciuciulkiene et al., 2023). According to (Kangas & Rasi, 2021) “This may be regarded as a response to critical statements proposing that traditional schools present too much theoretical and fragmented learning instead of linking it to real-world issues and problems” (as cited in (Ciuciulkiene et al., 2023).

Consequently, the opportunities afforded by such a curriculum are highly beneficial for students and teachers alike, and fully align with the official guidelines set forth by the Finnish National Board of Education (FNBE) for the development of learning to learn skills:

> The National Core Curriculum is based on a conception of learning that sees the pupils as active actors. They learn to set goals and to solve problems both independently and together with others. Learning is an inseparable part of an individual's growth as a human being and the building of a decent life for the community. Language, physical elements and the use of different senses are essential for thinking and learning. While acquiring new knowledge and skills, the pupils learn to reflect on their learning, experiences and emotions. Positive emotional experiences, the joy of learning and creative activities promote learning and inspire the pupils to develop their competence. (FNBE, 2016, section 2.3)

In light of the Finnish educational system, this approach could help address the tendency of secondary schools to be slow to respond to epochal shifts that are influenced by the economic, societal, cultural and technological foundations of society (McPhail, 2016).

Therefore, following the leading example of the Finish Educational System, EU schools and especially the ones of the partner countries -Italy, Greece and Cyprus- should make the necessary amendments to adopt in the official curricula PhenoBL. However, it is suggested that teachers should not be forced to work with teachers from different disciplines as this often leads to poor-quality sequences. An effective way to avoid this is through dialogue to clarify the aims of each discipline and how each discipline contributes to the purpose of the learning objectives and outcomes in understanding a subject (Tonnetti & Lentillon-Kaestner, 2023). The compendium seeks to overcome that barrier and the lack of frameworks and manuals to guide teachers in the implementation of interdisciplinary sequences (Fidalgo Neto et al., 2014; Ghisla et al., 2010; Hasni et al., 2015; Moss et al., 2019) as cited in Toneetti and Lentillon-Kaestner (2023). In this regard, the subsequent section of this chapter is dedicated to the detailed development of a phenomenon-based example and the provision of practical guidance to secondary educators on the implementation of this interdisciplinary lesson.

4.3 Practical Advice and Strategic Planning of an Interdisciplinary-PhenoBL lesson

To explore effective ways of actually implementing PhenoBL approaches within secondary school we discover and present the example provided by McPhail (2016) in their study “From aspirations to practice: curriculum challenges for a new ‘twenty-first-century’ secondary school”. The study elaborates on the school's vision and structure to challenge traditional notions of education, emphasizing the development of student dispositions and competencies through thematic, interdisciplinary, inquiry-based learning. Despite the global acceptance of these modern educational ideas, there is limited research on their impact on student outcomes. This study explores the challenges the school faced in translating its aspirational vision into a practical curriculum during its first 18 months. The focus is on the curriculum design and development process, offering insights relevant to educators worldwide engaged in new school planning and curricular innovation.

In the context of interdisciplinary curriculum design and Phenomenon-Based Learning (PhenoBL), practical advice and strategic planning are crucial for successful implementation. Here are some key points that educators and policy-makers should take into account according to the paper:

1. Clear Learning Outcomes: Clearly define the learning outcomes you want to achieve through interdisciplinary PhenoBL. Align these outcomes with the school's overall educational goals and objectives.
2. Collaborative Planning: Encourage collaboration among teachers from different disciplines to design integrated units that connect various subject areas around a central phenomenon or theme. This collaborative planning ensures coherence and alignment across subjects.
3. Professional Development: Provide teachers with professional development opportunities to enhance their interdisciplinary teaching skills and strategies. Training sessions, workshops, and resources can support teachers in implementing interdisciplinary PhenoBL effectively.
4. Flexible Scheduling: Consider the school schedule and timetable to allow for interdisciplinary blocks of time where students can engage in in-depth exploration of phenomena across subjects. Flexibility in scheduling is essential for meaningful interdisciplinary connections.
5. Student Engagement: Design learning experiences that actively engage students in exploring real-world phenomena. Encourage inquiry-based approaches, project-based learning, and hands-on activities to foster student curiosity and critical thinking skills.
6. Assessment Strategies: Develop assessment strategies that reflect interdisciplinary learning outcomes. Consider a mix of formative and summative assessments that evaluate students' understanding of concepts across multiple disciplines.

7. Reflection and Evaluation: Encourage regular reflection and evaluation of interdisciplinary PhenoBL units. Gather feedback from teachers, students, and stakeholders to continuously improve and refine the curriculum design.
8. Resource Allocation: Ensure adequate resources, materials, and technology support for interdisciplinary PhenoBL initiatives. .

Moreover, this study provides practical guidelines on how to plan an interdisciplinary PhenoBL module.

Small module planing overview.

Module title Familiar to unfamiliar	Learning Area 1: visual arts	Learning Area 2: technology
How might we relook at everyday objects and transform them from familiar to unfamiliar? We will be looking at everyday objects with a fresh viewpoint, exploring scale, form, and materials through drawing, modelling, designing, and making sculpture. Developing a design brief for sculpture opportunity. How might you develop a sculptural work that invites participation or challenges how we view everyday objects? Developing ideas, modelling and transforming scale and materials to produce sculptural artwork.		
Learning objectives: Term 3 Innovation	VA *to explore* by experimenting with sculpture process, techniques and materials.	Tech *to focus* by defining a brief and specifications for a sculpture opportunity.
Learning Objectives: Term 4 Transformation	VA *To generate* by producing a sculptural artwork.	Tech *to refine* by developing models and transforming materials
Links to:(prior learning, future learning, possible NCEA standards	VA: Links to *1.3 Achievement Standard* of developing work in more than one field of practice	Tech: Links to AS brief development. Development of conceptual design
Concepts	Creativity, creative action, problem-solving, scale, materials, materials, outcome development, transforming scale	Design for purpose (need/opportunity), scale, materiality, function and fitness for purpose, scale
Skills/tools	Sketching, process, techniques, sculptural process, maquettes, construction/ assemblage	Defining brief, developing specifications, 3D sketching, crating, modelling, sketch and scale modelling, prototyping, forming/transforming materials and scale
Curriculum strand	Practical knowledge (PK): exploring scale, materials/texture/properties and sculptural conventions, principles, elements Communicating and Interpreting (CI): describe own and others ideas practical knowledge; developing ideas (DI) Develop and revisit ideas, exploring scale, materials, form, techniques construction/ assemblage	Brief development technological knowledge: modelling
Contexts	Sculpture, relooking at familiar everyday objects, Claes Oldenburg, visit trusts, park seed pods, transforming size, texture, materials, purpose	3D sketching, crating, sculpture, public sculpture, interactive design, sculpture, everyday objects and function

Figure 1 as taken from McPhail (2006)

Figure 1 presents a small module planning overview that integrates Visual Arts and Technology under the theme of "Familiar to unfamiliar." This module aims to explore the transformation of everyday objects from familiar to unfamiliar by engaging students in activities such as drawing, modelling, designing, and creating sculptures. The key question posed is how students can develop sculptural works that challenge perceptions of everyday objects and encourage participation. By combining Visual Arts and Technology, the module emphasizes the exploration of scale, form, and materials, fostering creativity and innovation in students' artistic and technological endeavours. Through this interdisciplinary approach, students have the opportunity to develop critical thinking skills, engage in cross-disciplinary learning, and apply their knowledge in new and creative ways, aligning with the school's emphasis on integrated and experiential learning experiences.

In addition, Ivan Andreev in his article in Valamis a learning platform from a Finnish Enterprise who specializes in effective training provides five key questions that needs to be kept in mind when developing a PhenoBL module:

1. Have learners choose a “phenomena” from the real world; the topic should have a global context and be related to real life issues or events.
2. Develop an inquiry question around this topic that begins with either a “how”, “why” or “what if?”
3. Identify and teach the basic concepts that pertain to the learner’s chosen question; what skills or knowledge will they need to solve the problem?
4. Ensure that there is an open structure of time for learners to engage in the necessary research and problem solving.
5. Facilitate the process by setting up a framework that will help guide students through the process and develop their own way of solving the problem (Ivan Andreev, 2022)

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Conclusion

In an era where the boundaries between formal and informal learning are increasingly blurred and even the smallest action can have significant consequences, PhenoBL represents a radical departure from traditional educational approaches. The method immerses students in events and topics that seamlessly connect their academic subjects to real-life scenarios, thereby creating a powerful pedagogic approach that mirrors reality. The contemporary educational landscape requires that educational institutions provide learning experiences that are firmly rooted in real life. However, identifying the pedagogy that truly delivers on this promise has been challenging. Interdisciplinary learning often reverts to parallel learning, where students share a space but not a cohesive learning experience. The success of PhenoBL hinges on selecting appropriate phenomena using the ways and methodologies described in the previous chapters. Effective phenomena are timely, observable, and relevant, offering breadth and depth aligned with learning objectives. They should present multiple possibilities without predetermined solutions, intersect with society and academia, and carry meaning across various disciplines (Kennedy & Fields, 2023).

PhenoBL is aligned with the fundamental tenets of effective education, namely the role of teachers, the use of formative assessment, the value of reflection on learning, and the importance of scaffolding. It facilitates wellbeing in life by addressing real-world issues across disciplines. It promotes democracy, citizenship, and inclusion by engaging students in societal phenomena and encouraging diverse perspectives. Finally, it advances sustainable development by fostering interdisciplinary understanding and innovative solutions. Consequently, the following WP will endeavour to establish a correlation between the values and pillars of the 21st century, including wellbeing, democracy and sustainable development, with the objective of creating a Virtual Learning Lab that will equip EU teachers with the requisite knowledge and competencies to implement and adopt these values and pillars in the learning process.

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