COMPARATIVE STUDY OF INTERNATIONAL EXPERIENCES IN THE INTEGRATED TEACHING OF NATURAL SCIENCES

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Abstract: *Integrated teaching is an educational trend that equips students with the necessary skills and knowledge for the practical requirements of a volatile VUCA world. In Natural Sciences, integrated teaching not only helps students form the core scientific competencies but also prepares them to participate in the field of science, especially the STEM field and other interdisciplinary careers. The article presents the research and experiences of the Natural Sciences integrated teaching in some countries and regions around the world. Thereby providing approaches to help educators and teachers improve the quality of Natural Sciences teaching.*

Keywords: *Natural Sciences, integrated teaching, interdisciplinary teaching.*

I. Introduction

Integrated teaching is an educational approach in which teachers lead students to connect knowledge and skills in various fields to solve learning tasks or practical problems effectively. Besides that, students can actively gain new knowledge and skills based on their individual abilities and form problem-solving competency - a core and extremely important key in most current general education programs as well as in the context of social development [19]. In natural sciences, integrated teaching is even more meaningful when the world's development trend focuses on the STEM field, which requires the upcoming human resources to use interdisciplinary scientific skills and knowledge, innovative thinking, and the ability to adapt to practical requirements continuously.

So far, a lot of research on integrated teaching has been published, especially in some countries with a lot of experience implementing integrated teaching in natural sciences. From the qualitative methods on a theoretical and practical basis, this article aims to synthesize the research and experiences of some countries around the world in the integrated teaching of Natural Sciences and propose approaches to help the integrated teaching of Natural Sciences effectively implemented.

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II. Theoretical basic

2.1. Definition of Integrated Teaching in Natural Sciences

Thomas Hopkins (1937) is one of the first researchers to propose the concept of integration as "the combination of many subjects in a teaching topic" [14]. According to d'Hainaut (1977), there are four levels of content integration, including "disciplinary," "multidisciplinary," "interdisciplinary," and "transdisciplinary" [6].

In 1990, UNESCO published a study on trends of integrated teaching in Natural Sciences, which addressed the integration with Social Sciences and Technology [25]. In 2009, the National Association of Science Teachers in the United States proposed the concept of "STEM Education (Science, Technology, Engineering, Mathematics)," in which students will apply Science, Technology, Engineering, and Mathematics knowledge to specific contexts, helping them to develop competencies in STEM field [24].

In summary, it can be seen that integrated teaching in Natural Sciences is an approach that focuses on Natural Science and integrates with different fields to equip students with the interdisciplinary knowledge and skills to be able to solve learning tasks and practical problems of life.

2.2. Characteristics of Integrated Teaching in Natural Sciences

In terms of objectives, integrated teaching in Natural Sciences focuses on forming and developing learners' competency, especially practical problem-solving competency. Integrated teaching creates opportunities for learners to form relationships between subjects while reducing duplication between those subjects.

In the approach to integrated teaching, students are the center of learning activities, and teachers are the people who guide, suggest, and coordinate the activities. Integrated teaching often comes from a problem to be solved, a project to be implemented, or real-life applications. In addition, the assessment is also carried out in the orientation of competency, focusing on practical assessments, experiments, and learning products.

Additionally, to successfully implement integrated teaching in Natural Sciences, it is necessary to have core conditions such as developing the curriculum in the competency approach based on clear and measurable standards, developing education policies, and training teachers that have the capacity to execute the program.

2.3. Models of Integrated Teaching in Natural Sciences

Currently, there are three popular integrated teaching models in the world, namely the "Theme-based Model," "Interdisciplinary Model," and "Transdisciplinary Model" [13].

- ***Theme based Model***

Also known as the Multidisciplinary Model, it is a model in which different subjects will be carried out separately under a learning theme, but there is little connection between the subjects [11].

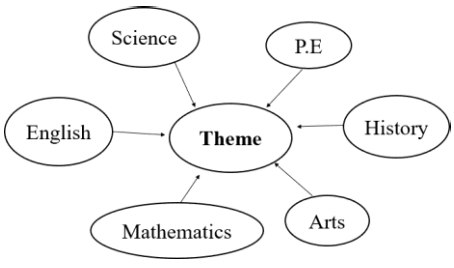

Figure 1. Multidisciplinary Approach (Drake, Burns, 2004)

For example, the theme "Sustainable Development" is planned in which Natural Sciences and Geography will be developed associated with the theme's objectives but in separate teaching:

Table 1. Subject integration based on the learning objectives within a theme teaching approach

Theme: Sustainable Development		
Theme objectives: - Students explore the concept of sustainable development. - Students explore the impact of human activities on sustainable development. - Students explore the application and propose a solution for sustainable development.		
Subject	Geography	Natural Sciences
Lesson	MOET Curriculum: Grade 6 Lesson 29: Sustainable development and natural resources exploitation.	MOET Curriculum: Grade 6 Lesson 50: Renewable energy.
Learning objectives	Students can answer the meaning of natural resource exploitation and list the activities involved in sustainable development.	Students can answer the definition and examples of renewable energy and list the applications of renewable energy for sustainable development.

- ***Interdisciplinary Model***

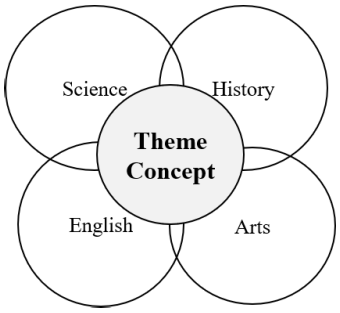

Figure 2. Interdisciplinary Approach (Drake, Burns, 2004)

The Interdisciplinary Model is improved based on the Multidisciplinary Model. However, instead of subjects being taught separately, they will be combined under a specific theme or lesson [11].

In this model, natural sciences and other subjects contribute or consolidate content to create a unified topic or lesson, with the contents interconnected between different subjects. For example, the theme "Sustainable Development" is conducted in a specific lesson with the connection, integration, and logical flow of teaching between Natural Sciences and Mathematics:

Table 2. Subject integration based on the learning objectives within an interdisciplinary teaching approach

Theme: Sustainable Development
Theme objectives: - Students explore the concept of sustainable development. - Students explore the application and propose a solution for sustainable development.
Lesson: Balanced menu
Lesson objectives: (1) Students can answer the characteristics and energy of many kinds of food (MOET Curriculum, grade 6, Natural Sciences, Lesson 15: Food). (2) Students can define the types of data: qualitative or quantitative data (MOET Curriculum, grade 6, Mathematic, lesson 38: Data and data collection). (3) Students can design a method to collect data on their daily food consumption (MOET Curriculum, grade 6, integration of Natural Sciences and Mathematics, Lesson 15: Food and Lesson 38: Data and data collection).

Therefore, according to Kiray (2011), teachers can set the ratio of content between integrated subjects. The author has presented how to put the content of Natural Sciences as the main focus and integrate a part of Mathematics or vice versa according to the following diagram:

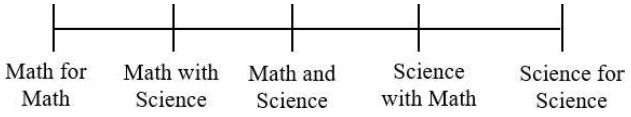

Figure 3. Continuum included in the models (Kiray, 2011)

- ***Transdisciplinary Model***

The transdisciplinary Model is considered the highest thinking level in which subjects are integrated together under a large learning topic, which is highly problematic because of the transdisciplinary content of different subjects. This content may include relational concepts, knowledge strands, and general skills. These contents are implemented centrally throughout the learning topic and help reduce the duplication of content between subjects in a curriculum [11].

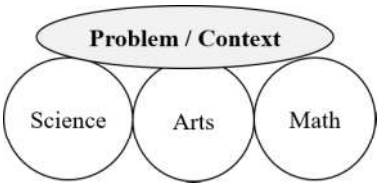

Figure 4. Transdisciplinary Model (Kaufman, Moss, 2003)

For example, the theme "Sustainable Development" is conducted with an integrated lesson and has high practicality and problem-solving between Natural Sciences, Mathematics and Arts:

Table 3: Subject integration based on the learning objectives within a transdisciplinary teaching approach

Theme: Sustainable Development
Theme objectives: - Students explore the concept of sustainable development. - Students explore the application and propose a solution for sustainable development.
Lesson: Natural skincare
Lesson objectives: (1) Students can describe the structure of human skin layers and their characteristics (MOET Curriculum, grade 8, Natural Science, lesson 39: Human skin system). (2) Students can describe the pH scale characteristics and its applications in skincare production and use (MOET Curriculum, grade 8, Natural Sciences, a combination of lesson 39: Human's skin system and lesson 9: pH indicator). (3) Students can collect data about skincare product consumption and customer insights about pH factors and then perform it by a graph (MOET Curriculum, grade 8, integration of Mathematics and Natural Sciences, lessons 18&19: Data collection, graph design, lesson 39: Human's skin system and lesson 9: pH indicator). (4) Students can research and propose a procedure to make a shower gel from natural materials and be able to adapt with the customer insights in a suitable pH range (advanced learning objective based on real life). (5) Students can describe the branding design's characteristics and design a specific and personal symbol or logo (MOET Curriculum, grade 8, Arts, lesson 8: Arts in household appliances). (6) Students can make the natural shower gel with a logo design, distribute it to the tester, and collect the data about the tester's feedback (advanced learning objective based on real life).

III. Research results

3.1. Findings

❖ *In the United States*

The integrated teaching tendency in Natural Sciences is mainly used in the United States as the interdisciplinary Model, which is taught with the interdisciplinary knowledge between Chemistry, Physics, and Biology from the periods of 1890s-1930s [11]. Since 2009, the concept of "STEM education (Science, Technology, Engineering, Mathematics)" has been the most remarkable Model implemented to help develop competencies in STEM fields [21].

Regarding teaching methods, "Inquiry-based learning" and "Interdisciplinary project-based learning" are commonly used in United States schools. In these methods, students engage in projects or inquiry processes to solve problems or propose solutions, connecting and applying their knowledge to real-life contexts. Additionally, other forms of teaching in Natural Sciences include "Learning through experiences," "Hands-on experiments," "Outdoor learning," "Technology-based learning," and "Research-based learning" [2].

The curriculum and teacher training also play significant roles in integrated teaching. Most United States secondary schools follow a standards-based curriculum, such as the "NGSS (Next Generation Science Standards)," "NSES (National Science Education Standards)," and "CCSS (Common Core State Standards)," to minimize outcome disparities across states [5] [18] [10]. While a single teacher typically conducts Natural Sciences, some schools still offer it as a separate subject. Teachers undergo annual training during the summer break for 5-6 weeks, participating in online courses, seminars, learning communities, and mentoring programs to enhance their teaching quality [1].

Besides the strengths of technology-based support and the partnership between Natural Science teaching in schools and industry, integrated teaching in the United States also faces many difficulties due to the lack of consistency in management, large class sizes, educational policies, and religious beliefs, which can hinder its effectiveness [23].

❖ *In European countries*

In European countries, the interdisciplinary Model is primarily applied to integrate Chemistry, Biology, and Physics for students aged 6-14. STEM competencies are largely developed through digital platforms such as MOOC (Massive Open Online Courses), interactive tools like STEM Lab, Virtual Lab, Minecraft Education Edition, Make Code, and hands-on toolkits like robots and 3D printers [17].

Regarding teaching methods in Natural Sciences, European countries emphasizeactivelearningapproachesbased on cognitive theories to foster students' competencies. Common procedures include "Project-based learning" [1], "Hands-on experiments," "Problem-based learning," and "Technology-based learning." Communication development is also encouraged through discussion, debate, and presentation, while experiences from "Fab labs" or "Maker spaces" are promoted to connect students with real-world scientific practices.

In terms of curriculum and teacher training, Europe does not have the standards due to its multi-ethnic political and cultural landscape. However, some standardized programs, such as the Cambridge and International Baccalaureate curricula [7], are widely recognized. For teacher training, the PROFILE model (Professional Reflection Oriented Focus on Inquiry-based Learning and Education through Science) is recommended to link teaching activities with inquiry-based learning [3].

Despite the success of integrated Natural Sciences teaching, supported by rich resources, funded projects, and collaborations between schools and experts,

there are still challenges. Public perceptions of science careers and gender discrimination are notable barriers impacting European access to science education [26].

❖ ***In African countries***

In African countries, integrated teaching in natural sciences is commonly applied as an interdisciplinary subject in primary and secondary schools. The focus is primarily on STEAM, ICT-based Science, and TVET (Technical and Vocational Education and Training) to develop students' competencies in Natural Sciences.

Regarding teaching methodologies, African countries have shifted from a traditional to an integrated approach in the 21st century, emphasizing a connection to local issues such as climate change, water scarcity, and housing. Using a "constructivist approach," teaching strategies include "Experiment-based learning," "Inquiry-based learning," "Project-based learning," and other forms such as science clubs, exhibitions, digital platforms, simulation tools (PhET), and MOOCs (Massive Open Online Courses) [21].

In adaptation to the integrated tendency revolution and real-world context, African countries focus on the competency-based curriculum and teacher training in which the teacher's competency framework is the most critical factor affecting the curriculum implementation. The ATQF (Continental Teacher Qualification Framework) is a prominent framework that outlines teacher development stages, from pre-service training to continuous professional development, expert-level qualifications, and accreditation [9].

Compared with other areas, the integrated teaching of natural sciences in African countries has developed gradually with technology and government support. However, several key issues prevent adequate integrated teaching results, including a shortage of qualified integrated teachers, overcrowded classrooms, lack of resources, weak physical infrastructure, outdated curricula, and inadequate content and pedagogical knowledge training.

❖ ***In Asian countries***

In Asian countries, Natural Sciences are taught as an integrated subject using interdisciplinary and transdisciplinary models at both the primary and secondary levels. STEAM is the most prevalent approach to integrated Science teaching, particularly in countries like Korea, Japan, and Singapore, where it is implemented through various pathways from local to national levels [4].

In terms of teaching methodologies, Asian countries emphasize technology-based teaching to enhance the quality of Natural Sciences education. Internet-based learning methods, such as MOOCs (Massive Online Open Courses), Blended learning, LMS (Learning Management Systems), AR-VR simulations, and software like Microsoft Teams, Zoom, and Google Classroom, are widely used by teachers to provide students with more learning opportunities. To connect learning with real-world contexts, approaches like scientist-teacher-student partnerships, industry-school collaborations, the engineering design process, online experiments, and mentor-mentee learning within universities are encouraged to develop STEM and problem-solving competencies. The technology aspect of STEAM is especially emphasized through Robotics and Coding lessons [23].

For curriculum design, school-based, stakeholder-based, and outcome-based curricula are the primary approaches influencing Natural Sciences education in Asian countries. Teacher training and professional development are also key components of national strategies. Models like PDCA (Plan, Do, Check, Act) and lesson-based professional development are used to foster teacher collaboration across different specialties and strengthen interdisciplinary relationships, using the available resources in schools [15].

Despite long-term strategies for developing and teaching integrated

science, Asian countries still face many challenges in training pre-service teachers in the university and a lack of consistency in textbooks [8].

3.2. Discussion

❖ *Summary*

To sum up, integrated teaching is an unavoidable tendency of general education, especially in the context of many social challenges and requirements set by the 4.0 revolution. From the experiences of the Natural Sciences integrated teaching in countries and regions such as the United States, Europe, Asia, and Africa, It can be seen that countries have implemented integrated teaching from a very early stage and contributed many positive results.

- *Tendency in Natural Sciences integrated teaching:*

If we consider integrated teaching according to a horizontal and vertical system:

+ Vertically: Most countries teach Natural Sciences under interdisciplinary topics at the primary level; integrated subjects include Chemistry, Physics, and Biology at the secondary level, and separate subjects at the high school level.

+ Horizontally: Natural Sciences is taught not only by the inner contents of the subject but also by other subjects, such as mathematics, technology, engineering, language, art, socio-emotional education, history, geography, etc.

- *Tendency in the integrated Natural Sciences curriculum development:*

It can be seen that each country and region has a different tendency to develop an integrated Natural Sciences curriculum. However, most curriculums focus on developing student competencies through student-centered models.

Some of the trends in curriculum development include:

+ Outcome-based approach;

+ School-based approach;

+ Stakeholders based approach.

- *Tendency in the teacher training to adapt to the requirements of the integrated Natural Sciences curriculum:*

Teacher competency is a significant factor that directly determines curriculum implementation. Some of the trends in teacher training in the world are overviewed, including:

+ By phase: including the pre-service and in-service teacher education. Each stage will include training activities in accordance with the goal of the career.

+ By scope: including in-school training and out-of-school training. Training in the school includes contents associated with the school's goals in the participation of the leadership, teachers, staff, and other members of the school organization. Out-of-school training emphasizes the participation of parties not belonging to the school organization, such as government departments, educational organizations, international organizations, and training centers.

❖ *Recommendations*

- *In teacher training:*

It enhances teacher competencies in Natural Sciences at the university, focusing on integrated teaching and experimental teaching competencies. This can be achieved by expanding the number of relevant subjects, extending the duration of courses, and diversifying the formats of experimental teaching. Additionally, it is essential to develop professional training activities that emphasize laboratory working and management skills. Furthermore, increasing the scope, duration, and variety of internships at schools, educational institutions, and industries will contribute significantly to the professional development of teachers in Natural Sciences.

- *In curriculum development:*

It establishes outcome standards in Natural Sciences that align with learners' capacities and meet the requirements of schools, local authorities, and national

expectations within a global context. It is essential to systematize these standards and develop standardized scales. Furthermore, it is crucial to provide guidance for teachers on implementing lesson plans, designing learning activities, and conducting assessments in accordance with these established standards.

- *In teaching and assessment approaches:*

They are fostering the development of students' competencies, emphasizing project-based, problem-based, inquiry-based, and experiential learning. The assessment methods should also be reformed to align with a competency-based approach, incorporating oral examinations, presentations, and exhibitions of student learning products.

IV. Conclusion

Integrated teaching is an educational approach that helps equip students with interdisciplinary competency to step into their careers. Especially for Natural Sciences, integrated teaching has become an even more remarkable highlight when the world's development trend requires human resources in STEM fields to use interdisciplinary scientific skills and knowledge, innovative thinking, and the ability to adapt to practical problems continuously. This study has completed two main objectives:

(1) Presenting the studies and experiences of various countries and regions around the world in the integrated teaching of Natural Sciences, (2) Drawing conclusions from practical experiences and proposing application approaches in the integrated teaching of Natural Sciences. Thereby, helping educators and teachers have a comparison from international experiences.

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NGHIÊN CỨU SO SÁNH KINH NGHIỆM QUỐC TẾ TRONG TỔ CHỨC DẠY HỌC TÍCH HỢP MÔN KHOA HỌC TỰ NHIÊN

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Tóm tắt: *Dạy học tích hợp là xu hướng giáo dục tất yếu nhằm trang bị cho người học những kĩ năng và kiến thức cần thiết trước những yêu cầu thực tế của một thế giới VUCA đầy biến động. Trong môn Khoa học tự nhiên, việc tổ chức dạy học tích hợp không chỉ giúp người học hình thành những năng lực khoa học cốt lõi mà còn chuẩn bị cho người học một hành trang để tham gia vào lĩnh vực khoa học đặc biệt là xu hướng nghề nghiệp STEM và các nghề nghiệp khoa học liên ngành khác. Bài viết trình bày các nghiên cứu và kinh nghiệm tổ chức dạy học tích hợp môn Khoa học tự nhiên của một số quốc gia trong khu vực và trên thế giới. Qua đó, đề xuất một số gợi ý giúp các nhà giáo dục, giáo viên nâng cao chất lượng hoạt động dạy học môn Khoa học tự nhiên.*

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