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SUMMARY OF THE DOCTORAL THESIS

THE INTEGRATION OF PROJECT-BASED LEARNING AND FLIPPED LEARNING IN PRIMARY SCIENCE EDUCATION

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INTRODUCTION

The contemporary educational context is marked by an increasingly pressing imperative: moving beyond the transmissive model of instruction and building learning environments that place the student at the centre of the teaching process. The knowledge society calls for graduates who are able not merely to reproduce information, but to apply it creatively, collaborate, solve complex problems, and reflect critically on their own learning. These demands require a fundamental reconsideration of the pedagogical paradigms used in schools.

This paper addresses two innovative instructional models that respond to these challenges: Project-Based Learning (PBL) and Flipped Learning (FL). The paper is structured in four complementary chapters, which trace a coherent path from the theoretical grounding of the two models, to the identification of their pedagogical convergences, and finally to the evaluation of the effectiveness of an integrated instructional model implemented in the primary school context.

The first chapter addresses the theoretical foundations of Project-Based Learning (PBL) — tracing its history, epistemological bases, representative models, the roles of the educational actors involved, and the results documented in the specialised literature — as well as of Flipped Learning, analysing the origins, definitions, theoretical foundations, and practical implications of this model. In addition, the chapter presents a comparative analysis of the two models, identifying their pedagogical convergences and structural complementarity from the perspective of Bloom's cognitive taxonomy.

Starting with the second chapter, four preliminary studies conducted prior to the experimental research are presented. The first study investigates teachers' perceptions of deep learning. The results of this study show that teachers are familiar with the use of deep-learning strategies, yet these coexist with various practices and features characteristic of surface learning. The paper continues with the presentation of the study investigating teachers' attitudes toward experimentation and demonstrative experimental activities. The analysis of the results indicates that, although teachers show motivation to use experiments and consider these activities educationally valuable, their level of confidence regarding the implementation of such activities in teaching practice is relatively low.

The third study presents teachers' perceptions of project-based learning, with an emphasis on the instructional practices used, student engagement, and the specific benefits of this educational approach. The study also investigates teachers' perceptions of experimental research. The results of this study highlight that teachers hold predominantly positive perceptions of project-based learning, while the analysis of their conceptions of experimental research shows a need for training in designing experimental inquiry activities.

The fourth study in this chapter aims to investigate teachers' perceptions of PBL implementation, the competencies students need in order to carry out project activities, and the role of reflection, assessment, and metacognition in the educational process.

The results of the four preliminary studies contributed to grounding and developing the experimental research carried out with primary school students. Thus, the study on teachers' perceptions of deep learning showed that, although teachers use strategies specific to deep learning, these frequently coexist with practices associated with surface learning. Based on these results, it was deemed necessary to design an instructional model that would place emphasis not only on memorisation but also on students' active cognitive engagement in the learning process. Accordingly, the experimental intervention sought to reduce the exclusive emphasis on reproducing information and to integrate activities centred on reflection, inquiry, and the transfer of knowledge to authentic contexts — regarded as key elements of deep learning.

The results of the second study, focused on teachers' attitudes toward experimentation and demonstrative experimental activities, revealed a discrepancy between the value placed on these activities and the low level of confidence in implementing them in practice. Accordingly, the teachers involved in the experimental research were provided with a clear, structured model of experimental activities, precisely in order to facilitate their classroom implementation and to reduce the difficulties associated with using experimentation in teaching. The results also supported the need to develop an instructional model that would facilitate the use of experimentation in a structured manner accessible to both students and teachers.

With regard to the study on teachers' perceptions of project-based learning, the results revealed positive attitudes toward this approach. Teachers recognise the benefits of this approach for student engagement and for applying knowledge in real contexts. However, the analysis of teachers' conceptions of experimental research indicated difficulties in designing and implementing experimental inquiry activities. These results are consistent with the conclusions of the previous study, which showed that, although teachers value experimentation and demonstrative experimental activities and are motivated to use them, their level of confidence regarding practical implementation is relatively low. In this context, the instructional model proposed within the experimental research addresses both dimensions identified in the preliminary studies simultaneously: on the one hand, it capitalises on teachers' openness to project-based learning, and on the other, it offers a clear, structured framework for organising inquiry and experimentation activities. The proposed model therefore has favourable premises for acceptance and implementation in educational practice, as it responds both to teachers' interest in active, authentic approaches to learning and to their need for methodological support in integrating experimental activities in the classroom.

Overall, the four preliminary studies contributed to shaping the integrated instructional model implemented in the experimental research, supporting the need for a pedagogical approach centred on active learning, inquiry, reflection, and the application of knowledge in authentic contexts.

The third chapter presents the experimental research carried out in primary education, in the subject of Natural Science, evaluating the impact of an integrated instructional model, based on combining the two strategies, on students' performance and investigative (inquiry) skills in the Natural Science curriculum.

The fourth chapter includes the general conclusions and discussion, concluding with the presentation of the original contributions of the research.

Through the results generated, the present paper contributes to extending the specialised literature on the use of active, constructivist instructional approaches in primary education, by coherently integrating project-based learning, flipped learning, and experimental inquiry into a unitary instructional model. The originality of the research lies both in the theoretical grounding of an integrated instructional model and in testing its effectiveness on the performance and investigative skills of primary school students in the subject of Natural Science.

The proposed model responds to real needs expressed by teachers: the difficulties involved in implementing experimental activities and the need for a clear structure for integrating project-based learning and experimental inquiry into teaching practice — needs which make the integration of flipped learning into the project-based learning process a novel contribution brought by the present paper.

CHAPTER I. THEORETICAL FOUNDATION

1. Project-Based Learning

1.1. Conceptual delimitations and historical landmarks

PBL is defined as an instructional strategy through which students acquire knowledge and skills by investigating a complex question or authentic problem over an extended period of time, the process culminating in a product or public presentation (Buck Institute for Education, 2019; Larmer et al., 2015). Hallermann et al. (2011) emphasise its intentional, curriculum-integrated character, Smith (2018) its temporal dimension, and Krajcik and Czerniak (2018) its disciplinary perspective. The strategy belongs to the family of authentic learning approaches (Stanley, 2018), alongside Problem-Based Learning, Discovery Learning, and Case Study, which share student accountability, ill-defined problems, and task authenticity (Condliffe et al., 2017; Strobel & van Barneveld, 2009). Its specificity lies in the fact that the project constitutes the unit of learning, not an add-on to teaching, with knowledge being built gradually and non-linearly throughout the inquiry (Krajcik & Shin, 2014).

Its theoretical grounding is linked to Dewey's pedagogy and to the concept of learning by doing, taken up by Kilpatrick (2001) in the Project Method. Dewey (2008) criticised this interpretation, warning that activity must not become an end in itself but must remain subordinate to the acquisition of knowledge and transfer — a founding tension that remains an open issue. The strategy was later consolidated through Thomas's (2000) synthesis and through the work of the Buck Institute for Education (Boss & Larmer, 2018).

1.2. Theoretical foundations and defined limits

The epistemological core of PBL is constructivist (Ismuwardani et al., 2019; Ravitz, 2010; Ulrich, 2016), with knowledge being built by anchoring new acquisitions in pre-existing structures (Ausubel, 1963) and through the discovery of conceptual relationships with teacher support. Piaget (1970) recommends experiences with an optimal level of familiarity and unfamiliarity, a principle transferable to the formulation of driving questions. The socio-constructivist dimension explains the emphasis placed on collaboration and scaffolding (Brown & Campione, 1994; Wenger, 1998), self-regulation theory describes the planning–monitoring–self-reflection cycle followed within projects (Zimmerman, as cited in Panadero, 2017), and self-determination theory explains the intrinsic motivation generated by task authenticity (Deci & Ryan, 2000). The critical perspective stems from cognitive load theory: minimally guided strategies can overload the working memory of novices (Kirschner et al., 2006; Sweller et al., 2011). This critique does not invalidate PBL, but rather delineates the conditions for its effectiveness — unguided inquiry is not well-implemented PBL. The teacher must ensure the baseline level of knowledge through direct instruction and guided inquiry prior to independent work (Cooper & Murphy, 2016; Kokotsaki et al., 2016; Mayer, 2004).

1.3. Key elements, roles, and assessment

The most influential model structures PBL around seven key elements: the driving question, sustained inquiry, authenticity, student choice, reflection, assessment and revision, and public audience (Boss & Larmer, 2018; Larmer et al., 2015). The question must be open-ended, ill-defined, and calibrated to students' potential (Ravitz, 2010; Smith, 2018); inquiry involves research, hypothesis formulation, and evidence-based argumentation (Krajcik & Czerniak, 2018); and the public audience gives students' work social meaning. Thomas (2000) proposes five minimal criteria, while Miller and Krajcik (2019) identify the project question and the authentic product as cross-cutting invariants.

The teacher becomes a designer of learning experiences, a facilitator, and a coach (Boss & Krauss, 2018; Fullan & Langworthy, 2013; Goodyear, 2015; Laurillard, 2012), taking on specific strategies such as building a learning culture, aligning with learning goals, scaffolding, and mentoring (Boss & Larmer, 2018). Students formulate their own questions, lead their own inquiry, and become aware of the real relevance of the product (Boss & Krauss, 2018), with autonomy supporting accountability (Kokotsaki et al., 2016) and self-regulation (Panadero, 2017); differences in level become a pedagogical resource through heterogeneous grouping and rubrics with explicit criteria (Hallermann et al., 2011; Smith, 2018), the strategy offering a valuable alternative for students with learning difficulties (Darling-Hammond et al., 2008) and a favourable context for reserved students (Macmath et al., 2017). Assessment is predominantly formative in nature and multi-source in structure (Guo et al., 2020; Larmer et al., 2015), feedback accompanies the entire process (Black & Wiliam, 1998; Hattie & Timperley, 2007), and reflection has a structural role, placing students at the higher levels of the taxonomy (Cooper & Murphy, 2016).

1.4. Implementation: stages, strategies, and forms of organisation

Implementation follows a coherent cycle, not a rigid linear sequence (Boss & Larmer, 2018; Larmer et al., 2015): launch through an entry event that generates cognitive dissonance and the formulation of the driving question (Boss & Krauss, 2018); sustained inquiry, the investigative core that activates application and analysis (Anderson & Krathwohl, 2001), facilitated through scaffolding and formative feedback, without directly supplying answers

(Cooper & Murphy, 2016); development of the product, followed by revision cycles that activate evaluation and creation (Guo et al., 2020; Smith, 2018); public presentation (Hallermann et al., 2011); and systematic reflection, the metacognitive mechanism through which students consolidate their learning (Panadero, 2017; Wiggins & McTighe, 2005).

The strategies integrated into these stages include modelling thinking (Marzano, 2018), the Think–Pair–Share technique (Brame, 2013), hands-on inquiry and experimentation (Songer & Kali, 2014), formulating "If… then…" predictions, graphic organisers, which reduce cognitive load (Sweller, 2020), and direct-teaching mini-lessons, launched when observation identifies a concrete conceptual need (Kirschner et al., 2006). Small-group work is the predominant form (Kokotsaki et al., 2016), with the NRC (2012) confirming the superior results of students who take on collective responsibility for learning; individual activity nonetheless remains essential during preliminary study and self-assessment stages (Panadero, 2017).

Two extensions hold major potential for primary education. Learning in nature capitalises on direct observation, sensory experience being, for 9–11-year-old students who are at the concrete operational stage, a cognitive necessity rather than a methodological add-on (Geary, 2008; Piaget, as cited in Schaffer, 2010). Guided individual study at home brings PBL closer to the flipped model: transferring basic direct instruction to the individual space frees up class time for higher-level cognitive activities (Bergmann & Sams, 2012a). At this age, such activities do not require sophisticated technology — observing a natural phenomenon or formulating a prediction removes the dependence on digital infrastructure (Strelan et al., 2020) — while also conferring personal relevance, a condition for intrinsic motivation (Deci & Ryan, 2000). The necessary precaution is structuring the activity through observation sheets and formative checks upon return to the classroom (Bransford et al., 2000).

1.5. Documented results and conditions for effectiveness

Students who take part in well-implemented projects gain a deep understanding of content and transfer their knowledge to new situations (Ravitz, 2010), with the literature indicating positive relationships with critical thinking, creativity, and argumentation (Condliffe et al., 2017). The meta-analysis by Balemen and Ozer Keskin (2018) confirms the strategy's effectiveness in teaching Science at all pre-university levels, while at the motivational level PBL stimulates intrinsic motivation (Sharma et al., 2020). Results are, however, conditional on implementation quality: Kokotsaki et al. (2016) identify four categories of conditions — support provided to students in planning, institutional support and ongoing teacher training, the quality of group collaboration, and reflection-centred assessment. Condliffe et al. (2017) and Hallermann et al. (2011) note the difficulties of using PBL in subjects with strongly procedural knowledge structures — an observation confirming that the strategy yields maximal results when the conceptual foundation has already been secured, either through direct instruction or through preliminary activities specific to FL. The literature also highlights considerable variability in effects and a weak representation of primary education in research on the integration of the two approaches.

2. Flipped Learning

2.1. Origins, definitions, and theoretical foundations

FL is regarded as an educational paradigm (Khadri & Khadri, 2016), the reference definition being that of the Flipped Learning Network (2014, p. 1): a pedagogical approach in which direct instruction moves from the collective learning space to the individual space, transforming the remaining collective space into a dynamic, interactive environment in which the educator guides students in applying concepts. The model does not represent a mere change in the location of teaching, but a reorganisation of the relationship between teaching, learning, instructional time, and individual responsibility (Persky & McLaughlin, 2017). Its origins can be traced back to Crouch and Mazur's (2001) longitudinal research on peer instruction and to the phrase inverted classroom introduced by Lage et al. (2000), while Bergmann and Sams (2012a), identified as pioneers, developed the model starting from the need to dedicate shared time to individualised support. Yarbro et al. (2014) note that the terms flipped classroom and flipped learning are not strictly synonymous, and Bishop and Verleger (2013, p. 5) define the model through its two components: interactive group activities in class and direct instruction delivered outside of class.

The theoretical frameworks of FL are constructivism and socio-constructivism (Bishop & Verleger, 2013; Tiba, 2025). Jarvis et al. (2014) highlight the relevance of the zone of proximal development: the student comes to class with an initial degree of familiarity, and collective time is used for clarification, deepening, and transfer. Persky and McLaughlin (2017) stress the need for constructive alignment among objectives, preparatory activities, in-class activities, and assessment; without this alignment, the model risks becoming a mere distribution of digital resources. Bloom's taxonomy legitimises the model's instructional structure (Brame, 2013), self-regulated learning theory explains the demand placed on students to organise their own time, cognitive load theory supports it through the possibility of reviewing and revisiting materials, and self-determination theory explains its effects on motivation (Deci & Ryan, 2000; Strelan et al., 2020).

2.2. Defining elements (FLIP) and the roles of the actors involved

FLN (2014) and Hamdan et al. (2013) describe the conceptual structure of FL through four elements: a Flexible learning environment, allowing progress at different paces (Yarbro et al., 2014); a Learning culture, based on accessibility, scaffolding, differentiation, and continuous formative feedback; Intentional content, whereby pre-class materials must provide a sufficient basis for applied activities (Persky & McLaughlin, 2017); and a Professional educator, prepared and engaged, who becomes a facilitator offering individualised support. Strelan et al. (2020) show that effectiveness depends on the degree of sophistication of the pedagogical design, with "classically flipped" classrooms differing substantially from minimal forms. The teacher is a designer of resources and a mediator of social interaction (Tiba, 2025), able to devote more time to individualised interaction (Ahmed, 2016). Students take part in activities that cannot be automated — discussions, debates, collaborative problem-solving (Bishop & Verleger, 2013) — and take on responsibility for prior preparation, which can lead to some resistance precisely because the model demands greater active engagement.

2.3. The technological environment, benefits, and challenges

Technology plays an instrumental role (Tiba, 2025); recorded lectures are as effective as face-to-face ones in transmitting basic knowledge (Bishop & Verleger, 2013), yet they are not mandatory, as static resources can effectively support preparation (Persky & McLaughlin, 2017). Strelan et al. (2020) recommend short, five-to-ten-minute segments accompanied by check-for-understanding tasks. Documented benefits include autonomy and flexibility, increased engagement and improved performance — particularly in applying knowledge (Tiba, 2025) — as well as more time available for higher-level cognitive activities, with immediate feedback (Ahmed, 2016). The meta-analysis by Strelan et al. (2020), which included 198 studies and 33,678 participants, found a moderate positive effect on performance, with the main explanatory factor being the opportunity to organise structured active-learning activities in class. The challenges reported are dependence on technology and the digital divide, the additional effort required of teachers (Bergmann & Sams, 2012b), and students' responsibility for prior preparation. The model is valuable not because it moves teaching into the digital environment, but because it transforms class time into a space for active learning.

3. Pedagogical convergences and the grounding of the integrated model

3.1. Common foundations

The strongest common denominator of the two models is their anchoring in the constructivist paradigm (Ismuwardani et al., 2019; Khadri & Khadri, 2016; Tiba, 2025). Kokotsaki et al. (2016) show that PBL relies on the contextualisation of learning, active student engagement, and the construction of knowledge through social interaction, while FL draws on the same logic by transferring basic acquisitions to the individual space (Persky & McLaughlin, 2017). The second common foundation is the socio-constructivist perspective: both models explicitly draw on the zone of proximal development and place scaffolding at the centre of the process (Hattie, 2014; Jarvis et al., 2014). This convergence is significant because it shows that both presuppose guidance rather than leaving students to face the task alone, thereby distinguishing themselves from minimally guided instruction (Kirschner et al., 2006). Also shared is a student-centred focus, the transformed role of the teacher, and the central role attributed to collaboration and multi-source formative feedback (Boss & Larmer, 2018; FLN, 2014; Jalinus et al., 2017).

3.2. Bloom's revised taxonomy and the distribution of activities

The taxonomy developed by Bloom (1956) and revised by Anderson and Krathwohl (2001) organises cognitive processes into six categories: remembering, understanding, applying, analysing, evaluating, and creating. Krathwohl (2002) points out that it functions as a common language for curriculum design, and the shift of the categories from nouns to verbs reflects the emphasis placed on the active character of learning, influenced by constructivist and self-regulation theories (Amer, 2006). FL can be interpreted as a reorganisation of activities according to these levels: the traditional model uses class time for the lower levels and transfers application and analysis to students' individual work, whereas the flipped model shifts the lower cognitive activities to the individual space and reserves shared time for the higher levels (Bishop & Verleger, 2013; Brame, 2013). PBL draws on the higher levels in an even more extensive way, involving inquiry, data interpretation, critical evaluation, and the creation of original products (Kokotsaki et al., 2016).

3.3. Structural compatibility and the integrated instructional model

Analysis of the distribution highlights the cognitive complementarity of the two models: FL creates the conditions for flexible access to basic content and for initial cognitive preparation, while PBL provides the authentic framework for turning this knowledge into concrete products and experiences. Bergmann and Sams (2014) and Tiba (2025) explicitly point out that the two fit together naturally: individual materials can serve as the preliminary study resources needed to launch a project, and in-class activities can serve as the space for collaborative inquiry. The meta-analytic conclusion that the main explanatory factor for the effectiveness of the flipped classroom is the opportunity to organise structured active-learning activities in class (Strelan et al., 2020) directly justifies this integration, since the project offers precisely a structured, authentic, and collaborative form of problem-solving (Kokotsaki et al., 2016).

The integrated model can be described as a five-stage process: individual access to introductory materials; checking initial understanding through questions, discussions, or formative tests; applying information in a collaboratively carried-out project task; analysing data, formulating solutions, and creating products; presenting, evaluating, and revising these products. Such a framework covers the entire taxonomic spectrum and supports the development of metacognitive and self-regulatory competencies (Amer, 2006). FL organises flexible access to knowledge, while PBL transforms this knowledge into action, product, and meaningful experience — a grounding which, together with the weak representation of primary education in the existing literature, supports the direction of the research presented in the following chapters.

CHAPTER II. PRELIMINARY STUDIES: TEACHERS' OPINIONS AND PERCEPTIONS OF DEEP LEARNING, EXPERIMENTAL ACTIVITIES, AND PROJECT-BASED LEARNING

The construction of the integrated instructional model proposed in the thesis was preceded by an exploratory stage consisting of four preliminary studies, intended to empirically ground the design decisions made for the experimental intervention. Before introducing a model combining flipped learning with project-based learning in the classroom, it was necessary to understand teachers' reported representations, attitudes, and practices, since the literature consistently shows that the effectiveness of an active method depends on the teacher's pedagogical conceptions, on the perceived usefulness of the method, and on the sense of competence in using it (Haatainen & Aksela, 2021; Habók & Nagy, 2016).

Together, the four studies cover the three key components of the proposed model: the deep processing of content, experimentation as an inquiry method specific to the Natural Sciences, and the project as a form of organising learning.

1. Study 1. Teachers' Opinions on Deep Learning

1.1. Conceptual landmarks

Deep learning entails an integrated approach to knowledge, the promotion of authentic learning, metacognition, and self-regulation, as opposed to surface and strategic learning, which are specific to those who memorise information in order to obtain good grades or pass an exam. The grounding of the concept stems from the research initiated by Marton and Säljö (1976), continued by Biggs (1987, 1999) and Entwistle et al. (1979), and further developed by numerous authors (Biggs & Tang, 2011; Entwistle, 2018; Hermida, 2015; Lublin, 2003; Matsushita, 2018). The foundation of the deep approach consists in identifying essential information, understanding it, and creating links between new and prior knowledge (Ciascai et al., 2011), so that learning becomes meaningful and leads to cognitive restructuring and academic progress (Millis, 2010). Practitioners of surface learning, by contrast, accept information without critical analysis, their main goal being to pass assessments (Houghton, 2004; Jensen & Nickelsen, 2008). Matsushita (2018) shows that Entwistle (2000), drawing on

Pask's (1976) theory, differentiates two strategies of the deep approach — holistic and serialist — and adds to the classic dichotomy the strategic approach, oriented toward assessment requirements (Richardson, 2005). The same student may approach a task differently depending on its content, context, and requirements, as well as on their own interests and motivation (Bain & Zimmerman, 2009; Ramsden, 2003; Richardson, 2000; Yew et al., 2016).

1.2. Purpose, research questions, and methodology

The study investigated the opinions of pre-university teachers regarding deep and surface learning, examining four dimensions: preparation for tackling a task, feelings experienced during learning, the strategies used, and other characteristics of the two approaches. The research questions addressed the characteristics of deep learning, the strategies associated with it, perceptions of surface learning, and the existence of differences based on teaching experience.

The research used a quantitative, descriptive, questionnaire-based survey design, administered online. The instrument consisted of 44 items selected and adapted from the ASSIST scale (Entwistle et al., 2000), rated on a five-point Likert scale; validation studies report Cronbach's alpha coefficients of .85 for the deep approach, .81 for the surface approach, and .83 for the strategic approach. Responses were processed by summing the percentages for steps 1–2 (disagreement) and 4–5 (agreement). The sample comprised 113 teachers, predominantly female (96.46%), teaching at preschool (44.25%) and primary (32.74%) level, 77% working in urban settings.

1.3. Results

The results concerning preparation for carrying out a learning task outline a working profile based on organisation, systematic thinking, planning, and consistent effort. The highest values were obtained for identifying favourable study conditions (M = 4.48; 93.81% agreement) and for carefully organising study time (M = 4.48; 88.50% agreement), and participants perceive themselves as systematic in preparing for exams (M = 4.15) — behaviours associated with self-regulated learning. The highest disagreement percentage (19.47%) was recorded for consistency of effort throughout the semester, the greater dispersion of responses signalling marked individual differences in the long-term management of academic tasks.

Regarding the feelings associated with the learning process, 32.74% of respondents often doubt that studying is worth the effort, 53.10% feel overwhelmed by the volume of materials, and 33.63% are worried they will not complete the task — an affective risk component that may favour a shift from the deep approach toward the surface approach.

Participants frequently use cognitive and metacognitive processes specific to deep learning: prior planning of how to approach a task (M = 4.58; 92.04% agreement), relating ideas to other topics or courses (M = 4.57), mentally representing the links between ideas (M = 4.56), critically analysing evidence (M = 4.16), reflecting while reading (M = 4.35), and monitoring their own performance — checking finished work (M = 4.46) and reviewing the coherence of their reasoning (M = 4.32). Notable exceptions are the item on questioning information received in an academic context (M = 2.42; 65.49% disagreement), which signals a low level of critical attitude toward educational sources, and the item on difficulties understanding content that needs to be retained (M = 2.17; 69.91% disagreement).

Regarding the general characteristics of deep learning, respondents report that they reflect on new ideas (59.29%) and go through the recommended resources (82.30%), with the study of academic materials considered interesting (88.50%) and enjoyable (82.30%); the motivation behind the effort, however, remains strongly anchored in the desire to obtain good exam results (87.61%). With regard to surface learning, most respondents centre their learning on what teachers say in class (80.53%), on what teachers consider important (78.76%), and on what seems necessary for assignments and exams (81.42%), and 62.83% admit they try to impress the teacher. By contrast, respondents reject memorisation as a dominant strategy (60.18% disagreement) and a strict orientation toward assessment requirements (76.11% disagreement).

1.4. Conclusions

Participants predominantly use strategies specific to deep learning — understanding, reflection, conceptual integration, planning, and monitoring — yet simultaneously display strategies associated with the strategic and surface approaches, especially a pronounced orientation toward the requirements set by the teacher and toward assessment performance. The coexistence of these two sets supports the idea that learning approaches are not disjoint categories, but dimensions that vary according to the academic context, educational requirements, and individual characteristics (Entwistle, 2000; Richardson, 2005). The implication for the experimental research was direct: the proposed instructional model needed to include explicit mechanisms for supporting deep processing, since mere exposure to complex tasks does not guarantee that reproductive strategies will be abandoned.

2. Study 2. The Attitude of Preschool and Primary School Teachers Toward Experimental Activities

2.1. Purpose and research questions

Attitude toward experimental activities is an important indicator of teachers' engagement in such endeavours, since experiments increase students' interest in the Natural Sciences and require them to test predictions, theories, and models (Chiaverina & Vollmer, 2005). The study investigated the attitudes of preschool and primary school teachers toward experiments and demonstrative experimental activities, focusing on their perception of the value and usefulness of these activities, their motivation to implement them, and their confidence in using them, as well as the relationships among these dimensions, the influence of certain demographic characteristics, and the perceived barriers.

2.2. Participants, instrument, and method

The sample comprised 95 early-childhood and primary school teachers, predominantly female (96.8%), of whom 53.7% held tenured positions. Beginning teachers (49.5%) and those with a definitive teaching certificate (36.8%) predominated, 81.1% having less than five years of teaching experience, and most worked in schools with fewer than 500 students (65.3%), relatively evenly distributed between rural (49.5%) and urban (43.2%) settings.

The instrument was adapted from the scale developed by Vlachos et al. (2024), with items expanded so as to assess in parallel attitudes toward experiments and toward experimental simulation activities: 31 items grouped into six dimensions (enjoyment, value and usefulness, motivation, confidence, reasons for non-implementation, comparative advantages), measured on a five-point Likert scale. The Cronbach's alpha coefficient obtained was .918. The questionnaire was administered online, with mandatory items to avoid missing values.

2.3. Results

Participants show positive attitudes toward the use of experiments. The value-and-usefulness dimension recorded the highest mean (M = 4.457, SD = 0.713), with the low standard deviation indicating a high level of consensus. Motivation also obtained a high mean (M = 4.231, SD = 0.825), with slightly greater variability. In sharp contrast, confidence in implementation recorded a considerably lower mean (M = 2.229, SD = 0.948), signalling consistent uncertainty about actually putting these activities into practice.

Correlational analysis revealed a positive, moderate, and significant relationship between the perceived value and usefulness of experiments and motivation to carry them out in class ($\rho = .515$, $p < .001$). By contrast, the relationships between confidence in implementation and the other two dimensions were negative, very weak, and non-significant ($\rho = -.134$, $p = .195$, and $\rho = -.113$, $p = .274$, respectively) — a pattern suggesting that appreciating pedagogical value and motivation do not automatically translate into a sense of practical competence.

Demographic comparisons showed no significant differences in perceived value (tenure status: $t = .165$, $p = .869$; setting: $t = -1.094$, $p = .277$) or in motivation ($t = -.657$, $p = .513$, and $t = -.967$, $p = .337$, respectively). The only significant difference concerned confidence in implementation, with non-tenured teachers reporting a higher level ($M = 2.461$) than tenured teachers ($M = 2.029$), $t = -2.219$, $p = .029$, with a small effect size. ANOVA analyses by teaching grade and teaching experience showed no significant differences for any of the three dimensions ($F(3, 91) = 2.098$, $p = .106$; $F(3, 91) = 0.818$, $p = .487$; $F(3, 91) = 1.477$, $p = .226$; and $F(5, 89) = 1.739$, $p = .134$; $F(5, 89) = 1.365$, $p = .245$; $F(5, 89) = 0.266$, $p = .931$, respectively). The use of ANOVA was considered appropriate despite moderate deviations from normality, this analysis being robust to such violations (Field, 2018).

2.4. Conclusions

The results reveal generally positive attitudes toward experiments, relatively homogeneous across the sample regardless of teaching grade, professional experience, tenure status, or institutional setting. The central conclusion, however, is the existence of a consistent discrepancy between the theoretical appreciation of the value of experiments and teachers' sense of competence regarding their implementation: teachers consider experiments useful and want to use them, without feeling sufficiently prepared to carry them out. The barriers reported confirm the pragmatic nature of the difficulties: limited time for experiments (55.8% cumulative agreement) and for demonstrative activities (54.7%), pressure to comply with the curriculum (51.5%), and multiple institutional responsibilities (41.1%), together with a lack of practical experience and insufficient specific training. Unlike the results reported by Vlachos et al. (2024), the present study found no attitudinal differences based on teaching experience or educational background. This finding directly informed the design of the experimental intervention, which was oriented toward detailed support materials and easily operationalisable activity protocols.

3. Study 3. The Relationship Between the Implementation of Project-Based Learning and Conceptions of Experimental Research

3.1. Conceptual framework and purpose

Project-Based Learning (PBL) is considered one of the most effective methods for developing 21st-century competencies, being a constructivist approach that facilitates student engagement in investigating authentic problems and in creating educationally relevant products (Bell, 2010; Kaldi et al., 2011; Markula & Aksela, 2022). The effectiveness of the method, however, depends on the instructional practices used, on teachers' perceptions of its benefits, and on how they understand the inquiry processes specific to active learning (Haatainen & Aksela, 2021; Habók & Nagy, 2016).

The study aimed to investigate the perceptions of primary and preschool teachers and pre-service teachers regarding PBL implementation — through the analysis of instructional practices, student engagement, and perceived benefits — and to explore the relationship between these dimensions and conceptions of experimental research.

3.2. Participants, instrument, and method

The sample comprised 91 teachers and pre-service teachers, predominantly tenured (81.3%), holding teaching grade I (63.7%), from urban settings (62.6%). The instrument included demographic items, the three dimensions of the questionnaire on perceptions of PBL (Ling et al., 2024) — instructional practices (8 items), student engagement (7 items), and perceived benefits (5 items) — and a subscale on conceptions of experimental research (7 items). Internal consistency was excellent for the first three subscales ($\alpha = .904$, $\alpha = .942$, and $\alpha = .914$, respectively) and acceptable for the epistemological subscale ($\alpha = .625$). The design was quantitative, cross-sectional, and correlational; the data were processed in IBM SPSS Statistics 21, and normality tests indicated significant deviations ($p < .05$), which is why inferential analyses used non-parametric tests.

3.3. Results

Participants show generally positive perceptions of PBL implementation, with the highest values recorded for perceived benefits ($M = 4.45$) and instructional practices ($M = 4.38$), while conceptions of experimental research have a moderate mean value ($M = 2.99$), suggesting varied perspectives on the processes of scientific knowledge construction. Correlational analysis revealed significant positive associations among the PBL dimensions: instructional practices correlated with student engagement ($\rho = .593$, $p < .001$) and with perceived benefits ($\rho = .386$, $p < .001$), and student engagement correlated with perceived benefits ($\rho = .383$, $p < .001$). Conceptions of experimental research correlated significantly, though with low-to-moderate intensity, with student engagement ($\rho = .284$, $p = .006$), with perceived benefits ($\rho = .251$, $p = .017$), and with the overall PBL score ($\rho = .291$, $p = .005$); the relationship with instructional practices did not reach the threshold of significance ($\rho = .158$, $p = .134$).

The Mann–Whitney U test showed no significant differences in the overall PBL score based on institutional setting ($U = 866.50$, $Z = -0.149$, $p = .882$), and the Kruskal–Wallis tests showed no differences based on professional experience, $\chi^2(6) = 8.476$, $p = .205$, or on teaching grade, $\chi^2(4) = 0.609$, $p = .962$. The hypothesis that more experienced teachers implement PBL to a greater extent was therefore not confirmed.

3.4. Conclusions and limitations

Teachers and pre-service teachers show predominantly positive perceptions of PBL implementation, particularly appreciating the method's educational benefits. The positive correlations among PBL practices, student engagement, and perceived benefits confirm the interdependence of these dimensions: the more frequently teachers use project-type practices, the higher the student engagement they perceive and the more they value the benefits of the approach. The positive, low-to-moderate associations between perceptions of PBL and conceptions of experimental research support the idea that the use of active strategies is associated with an epistemological orientation closer to experimental inquiry.

The limitations of the study include the small sample size and non-random selection, data collection based exclusively on self-report — with the risk of social desirability — the cross-sectional design, which does not allow causal inferences, and the moderate internal consistency of the epistemological subscale.

4. Study 4. Teachers' Perceptions of PBL Implementation, the Competencies Required of Students, and the Role of Reflection, Assessment, and Metacognition

4.1. Purpose, participants, and instrument

The fourth study investigated teachers' perceptions of PBL implementation, of the competencies students need in order to carry out project activities, and of the role of reflection, assessment, and metacognition. A mixed-methods approach was used, combining the descriptive analysis of quantitative data with a thematic analysis of open-ended responses, with qualitative coding carried out in MAXQDA.

The questionnaire was completed by 189 respondents, predominantly female (95.2%), with young teachers predominating (38.6% in the 20–25 age category) and those with under five years of experience (62.4%), specialising in preschool (44.4%) or primary (30.7%) education, from urban (53.4%) and rural (46.6%) settings. The instrument comprised 22 items: demographic data (8 items) and questions concerning project activity (14 items, of which 12 closed and 2 open).

4.2. Quantitative results

Project integration is distributed almost equally between extracurricular (50.3%) and curricular (49.7%) activities. The most frequent source of a project topic is a student learning need (67.7%), followed by everyday life (61.9%) and a local community problem (33.3%). Most respondents believe that student tasks should not be identical (52.9%), and only 16.4% support having identical tasks.

Regarding the support students need, participants most frequently indicate providing a work guide (86.8%) and offering assistance throughout the activities (82.5%). The preferred sources of documentation are those validated by the teacher — atlases or encyclopaedias (82%), books or textbooks (76.7%) — whereas unfiltered web pages are mentioned much less often (41.3%).

Regarding assessment, most respondents state that the teacher provides feedback whenever considered necessary (51.3%), and the majority (73.0%) believe that quality criteria should be designed jointly by teachers and students. The most common way of assessing project success was analysis of the results (48.1%), followed by combining process analysis with results analysis (40.7%), and the use of technology is considered useful by an overwhelming majority (95.2%).

4.3. Thematic analysis of the competencies required of students

Responses to the open-ended question on the competencies needed to implement PBL were analysed through inductive coding, with codes generated directly from the text and subsequently organised hierarchically into eight thematic categories.

The category with the highest frequency is Collaboration (161 references), indicating the central role of the social dimension in participants' representations, followed by Organisation and management (123 references), which highlights the importance of planning and coordination, Cognitive and academic skills (81 references), and Research (54 references), where participants particularly value the ability to select and critically evaluate information.

The visual analysis carried out using MAXQDA's Document Portrait function revealed frequent alternation among the codes, suggesting the multidimensional nature of the competencies associated with PBL and the interdependence among social, cognitive, and practical competencies.

4.4. The role of reflection, assessment, and metacognition

The thematic analysis identified several recurring themes. The most frequent was awareness of one's own learning process (45 occurrences): reflection and metacognition help students understand how they learn, identify their strengths, and monitor their progress. The second theme was feedback and self-assessment (38 occurrences), with assessment perceived as a source of clear benchmarks for improving performance.

These are followed by the development of critical thinking (30 occurrences), autonomy and self-regulation (27), deep learning and knowledge transfer (24) — with reflection and assessment described as mechanisms through which project activities turn from mere practical tasks into authentic learning experiences — and responsibility and active engagement (18).

4.5. Conclusions

Project-based learning is perceived as a complex, effective approach for the integrated development of students' cognitive, social, and practical competencies, with emphasis placed on collaboration, organisation, and critical thinking — results supported by the specialised literature (Rehman et al., 2024; Xu et al., 2023). The role of reflection, assessment, and metacognition in developing autonomy and self-regulation is consistent with the results reported by Zhang and Ma (2023), who point out that PBL fosters deep understanding of content, motivation, and self-reflection competencies.

5. Synthesis of the Preliminary Studies and Implications for the Experimental Research

Taken together, the four studies point to three findings with direct value for the design of the experimental research. First, teachers report predominantly deep information-processing strategies, while simultaneously maintaining a strong orientation toward assessment requirements and toward the guidance of the teaching authority (Study 1). This result confirms the coexistence of approaches described in the literature (Entwistle, 2000; Richardson, 2005) and justifies including, in the proposed model, tasks that cannot be solved through reproduction and negotiated, transparent assessment criteria.

Second, there is a significant discrepancy between the value attributed to experimental activities and confidence in implementing them (Study 2), explained not by experience, teaching grade, or setting, but by practical barriers — time, curricular pressure, resources — and by the absence of applied training. This finding supported the decision to build detailed support materials, with operationalised work protocols for each activity.

Third, favourable perceptions of PBL are widespread and homogeneous across professional categories (Studies 3 and 4), and orientation toward PBL is positively associated with more elaborate conceptions of experimental research. Teachers identify, as conditions for success, a set of competencies that go beyond subject content: collaboration, organisation, critical selection of information, communication, and reflection — competencies that correspond to the components which the integrated model proposed in the thesis seeks to develop by combining flipped learning with project-based learning in the subject of Natural Science.

The preliminary stage therefore provided both the empirical justification for the intervention and concrete design benchmarks: explicit scaffolding for experimental activities, work guides and process assistance, assessment criteria built together with students, and the systematic use of reflection and metacognition.

CHAPTER III. EXPERIMENTAL RESEARCH: EVALUATING THE EFFECTIVENESS OF AN EDUCATIONAL INTERVENTION BASED ON INTEGRATING FLIPPED LEARNING WITH PROJECT-BASED LEARNING

1. Introduction

The present research aims to evaluate the effectiveness of an integrated instructional model that combines Flipped Learning (FL) with Project-Based Learning (PBL), applied to the subject of Natural Science in primary education. The experimental research constitutes the central component of the doctoral endeavour and was preceded by four qualitative and quantitative preliminary studies, intended to ground the need for, and the direction of, the proposed instructional model.

The research process starts from the observation that traditional, predominantly expository teaching models no longer meet the demands of contemporary education, which is oriented toward competency development and toward students' active engagement in constructing their own knowledge. In this context, a mixed model is proposed and experimentally tested, in which introductory activities and basic cognitive processing are moved outside the classroom, through Flipped Learning (Bergmann & Sams, 2012a), while class time is dedicated entirely to the investigative, collaborative, and applied activities specific to Project-Based Learning (Thomas, 2000).

The thesis's research process was structured progressively, starting with an analysis of the theoretical foundations of the two instructional models, continuing with an investigation of teachers' perceptions, and concluding with the experimental validation of the integrated instructional model, described in Chapter III. The practical implementation difficulties identified in the preliminary studies — related to organising inquiry activities, managing projects, and using experimentation — led to the emergence of a need for a mixed model able to effectively support teachers in designing Natural Science lessons.

2. Research Problem, Relevance, and Motivation of the Topic

The research problem concerns determining the effectiveness of an integrated instructional model, based on FL and PBL, compared with the traditional teaching model, with regard to student progress and the development of cognitive competencies in the subject of Natural Science. Integrating the two models contributes to deep learning by activating the higher cognitive levels of Bloom's taxonomy, enabling not only the acquisition of knowledge but also the development of analysis, argumentation, and creation abilities, essential for students to adapt to the demands of contemporary society.

The relevance of the topic is supported by the need to optimise the instructional process in primary education and to increase students' engagement in meaningful learning activities. The education system faces pressure to adopt student-centred instructional strategies capable of responding to contemporary educational changes, and the integration of FL with PBL is presented as a coherent response to this pressure, through the explicit activation of the higher levels of Bloom's revised taxonomy (Anderson & Krathwohl, 2001).

The motivation for choosing this topic derives from the conviction that effective learning cannot be reduced to the transmission of information, but requires students' active engagement in authentic learning situations relevant to their everyday experience. The combination of PBL and FL is presented as an educational context in which students become active participants, able to investigate, formulate hypotheses, collaborate, and construct their own knowledge. The research aims to make a practical contribution to grounding the use of integrated instructional models in primary education, by providing empirical data on their effectiveness in developing cognitive competencies.

3. Purpose, Objectives, and Hypotheses of the Research

3.1. Purpose of the research

The general purpose of the research is to comparatively evaluate the impact of the integrated mixed instructional model against the traditional teaching model, with an emphasis on the higher cognitive levels of Bloom's revised taxonomy. The aim is to demonstrate that organising learning through guided individual study at home (the Flipped Learning component), followed by applied and investigative activities in class and by the creation of authentic products (the Project-Based Learning component), leads to deeper, more transferable learning (Perkins & Salomon, 1992), reflected in higher results on school assessments.

3.2. Research objectives

The general objective of the research is to evaluate the impact of the integrated mixed model, compared with the traditional model, on the school performance of primary school students in the subject of Natural Science. Five specific objectives derive from this: determining the initial level of preparation of students in both groups, through the administration of pretests; implementing the mixed model in the experimental group, over the course of the targeted content units; comparing the results obtained on the initial and final assessments, within each group, both separately and correlated across the two grade levels; analysing performance differences, both overall and at each level of Bloom's taxonomy; and investigating the development of investigative competency — hypothesis formulation and experiment planning — as a specific indicator of the model's impact.

3.3. Research hypotheses

The general hypothesis of the research states that implementing the integrated FL and PBL model leads to higher school performance in Science, compared with implementing the conventional/traditional model, among primary school students. School performance in Science is operationalised as students' knowledge and skills across the six levels of Bloom's taxonomy. The differentiation of performance across Bloom levels is theoretically grounded in the premise that Flipped Learning activates, in the student's individual space, levels 1–2 (remembering and understanding), thereby freeing up class time for levels 3–6 (applying, analysing, evaluating, and creating), where Project-Based Learning primarily operates (Bishop & Verleger, 2013).

Three secondary hypotheses derive from the general hypothesis. The first (SH1) states that integrating flipped learning with project-based learning significantly influences student performance in Science, compared with traditional teaching methods. The second (SH2) states that the effects of the educational intervention differ according to the cognitive level within Bloom's revised taxonomy, with the strongest effects expected at the higher cognitive levels. The third (SH3) states that the effect of integrating FL with PBL on the development of cognitive competencies differs between third-grade and fourth-grade students, particularly at the higher cognitive levels of Bloom's revised taxonomy.

3.4. Research variables

The independent variable is the type of instructional intervention, namely the use of the mixed model integrating Flipped Learning with Project-Based Learning. The dependent variables are represented by student performance in the subject of Natural Science, measured through a knowledge and skills assessment test structured according to the levels of Bloom's taxonomy. Control variables include grade level, curricular content, the textbook used (Editura Art Klett), the duration of the intervention, assessment conditions, and the general characteristics of the students, all of which were verified by standardising the experimental conditions between the two groups.

4. Research Methodology

4.1. Type of research

The research is a quasi-experimental pedagogical study, with a pretest–posttest design and a control group (Campbell & Stanley, 1963; Cohen et al., 2018). Unlike pure experimental research, which requires random assignment of participants to groups, the quasi-experimental design used by the author draws on naturally occurring groups — already-formed classes — a solution required by the educational reality, in which individual randomisation is not possible. The design comprises three essential stages: the pretest stage (week 0), in which both groups are assessed under identical conditions; the intervention stage (6 weeks for third grade, and 9 weeks for fourth grade), in which the experimental group is taught through the mixed model and the control group through traditional methods, with no changes to the usual instructional process and the same curricular content; and the posttest stage (week 7 and week 10, respectively), in which both groups are assessed again.

4.2. Research sample

The research sample comprised 261 students, distributed across 12 urban classes: 6 classes (141 students) in the experimental group — 3 third-grade and 3 fourth-grade classes — and 6 classes (120 students) in the control group, with the same distribution across grade levels. The selection criteria concerned comparability between groups: enrolment in mainstream urban education, use of the same textbook (Editura Art Klett), a comparable level of initial preparation — verified through pretest results — and consistent participation in instructional activities, under conditions compliant with the national curriculum (Ministry of National Education, 2014).

Students were assigned to groups randomly, and participation in the research was voluntary, with the students selected being those whose parents responded affirmatively to the request to take part in a pedagogical study. Participants came from three secondary schools in urban areas, and the school with the largest number of participating students was designated as the experimental group. This method of forming the groups is characteristic of quasi-experimental research carried out in real school settings, giving the results a high degree of ecological validity, given that rigorous control of all variables is not possible.

4.3. Instructional intervention

The instructional intervention was carried out in the subject of Natural Science, targeting two content units, adapted to each grade level. In third grade, the intervention covered the Life Science unit, with lessons on the characteristics of living things, groups of insects, birds, mammals, fish, amphibians, and reptiles, organisms' reactions to changes in the environment, as well as human activity and rest. In fourth grade, the intervention addressed the Physical Science unit — Bodies and Properties, with lessons on the properties of water, the floating of objects, mixtures and their separation, dissolving, changes in the characteristics of bodies and materials (burning, baking, spoiling, rusting), heat transfer, electric current, and light-related phenomena.

Each lesson in the experimental group was structured around the five stages of the mixed model, applied uniformly at both grade levels, with the necessary content adaptations. The first stage, carried out at home and corresponding to the Flipped Learning component, involved watching an introductory video, completing sentence-completion exercises or answering questions, examining images from the textbook, with the aim of reactivating prior knowledge, as well as formulating a “question of the day” related to the lesson topic. In fourth grade, the at-home activity included, in certain lessons, carrying out a simple experiment.

The following four stages took place in class, within the Project-Based Learning component. The second stage consisted of checking the knowledge acquired at home, through a short oral test and through the individual or paired presentation of notes taken. The third stage, considered the central moment of the lesson, involved presenting a thought-provoking situation or a problem question, followed by an actual inquiry process, in which students, organised into groups, formulated “If… then…” hypotheses, planned an experiment or observation, listed the necessary materials and actions, recorded their observations, and formulated a causal explanation. For example, in the lesson on the characteristics of living things, students planted seeds in pots and formulated hypotheses about the conditions needed for plant growth; in the lesson on the properties of water, students set up a “water analysis laboratory”, comparing samples from different sources (standing water, running water, tap water, bottled water) by appearance, colour, and smell.

The fourth stage consisted of a systematisation mini-lesson, always held after the inquiry activity, never before it, through which the teacher consolidated on the board the scientific terminology and the knowledge discovered by students during the inquiry stage. The fifth stage involved creating a concrete, tangible product that would demonstrate learning and require levels 5–6 of Bloom's taxonomy — for example, a “plant journal” in third grade, or a leaflet about sources of drinking water in fourth grade — followed by a brief metacognitive reflection activity, structured around four Bloom levels.

The timing protocol for each lesson was rigorously established: the first few minutes were dedicated to checking the at-home activity and activating prior knowledge, followed by a Think-Pair-Share discussion on the thought-provoking situation; the actual inquiry took approximately fifteen minutes, with the distribution of materials and active monitoring of student groups; the systematisation mini-lesson lasted ten minutes; carrying out the PBL project took another fifteen minutes; and the last five minutes were reserved for presenting the finished product. Adherence to this sequence — particularly the order inquiry–mini-lesson–design/creation of the product — was considered the essential condition for fidelity of implementation of the model, an aspect relevant to the internal validity of the quasi-experimental research (O'Donnell, 2008).

The intervention's timetable was uniform for both grade levels: week 0 was dedicated to the pretests; this was followed by 6 weeks of intervention in third grade and 9 weeks in fourth grade, with one lesson per week applying the integrated mixed model; weeks 7 and 10, respectively, were reserved for the posttests, and the last week was reserved for comparative data analysis. This structure allowed for a gradual, monitored implementation of the model, with emphasis placed on the fact that the sequence of the five lesson stages is not interchangeable: the systematisation mini-lesson must always follow, and never precede, the inquiry process, precisely so as not to undermine the investigative, discovery-based nature of students' learning.

The types of activities used included thematic projects, simple experiments, inquiry and problem-solving activities, and the teacher acted as a facilitator of learning, an organiser of activities, a guide in the inquiry process, and a provider of continuous formative feedback. Within PBL-based activities, students produced simple experiments, worksheets and observation sheets, individual or group thematic presentations, as well as applied mini-projects — posters, leaflets, experiment descriptions, simple reports. Implementation fidelity was systematically verified by the teacher-researcher, through monitoring the quality of classroom activity, the thought-provoking situations generated for Stage 3 of each lesson, the grounding of the mini-lessons, discussions with classroom teachers regarding implementation, tracking the creation and presentation of the PBL product in each class, as well as recording any issues related to the application of the integrated mixed model. The control group continued its usual instructional activity, with no intervention in the traditional instructional process, following the same curriculum and the same content as the experimental group.

As an illustration, the research includes the detailed structure of two lessons — one for each grade level. In third grade, the lesson on the characteristics of living things starts, at home, with watching an introductory video and completing, in the notebook, sentences about how plants make their food and about how animals feed and reproduce. In class, students are confronted with a thought-provoking situation — dried-out plants observed in the school corridor — and with the question “Why don't plants live under any conditions?”; they plant seeds in pots, formulate a hypothesis such as “If we water them and they have light and warmth, then they will grow and develop,” and the teacher subsequently consolidates on the board the common characteristics of living things — birth, growth, development, reproduction, and death, as well as the need for water, air, light, warmth, and food — the lesson ending with the creation of a "Plant Journal."

In fourth grade, the lesson on the properties of water starts with two videos on the states of water and with examining images from the textbook, with students noting the state of water shown in each image. In class, the thought-provoking situation is a news report about coloured, foul-smelling tap water in a locality, and the driving question is "Can water make you sick?" Students set up a "water analysis laboratory", collecting samples from different sources — standing water, running water, tap water, bottled water — and formulate several "If… then…" hypotheses regarding the colour, clarity, and smell of the samples, depending on the source, the lesson ending with the creation of a leaflet about sources of drinking water.

4.4. Data collection instruments

Data were collected through four assessment tests — one pretest and one posttest for each of the two grade levels — administered identically to both groups. Each item on each test was labelled with the Bloom's taxonomy level it targeted, allowing progress to be analysed at each individual cognitive level: remembering, understanding, applying, analysing, evaluating, and creating (Anderson & Krathwohl, 2001).

The initial test for third grade comprised six main items of increasing cognitive complexity: identifying the properties of water (level 1), explaining the lightning phenomenon (levels 1–2), identifying natural resources from the forest useful for starting a fire (level 2), a decision regarding the recycling of an object made of several materials (levels 2–3), identifying correct recycling behaviour (levels 2–3), and a complex item with six sub-requirements, which required identifying the causes of a small boat's movement on water, formulating a hypothesis, drawing up a list of materials, describing the steps of the experiment, recording observations, and formulating a causal explanation, thereby covering levels 2–5 of the taxonomy. The initial test for fourth grade followed a similar structure, with items on the types of rivers in Romania, the function of the layer of fat on a duck's feathers, water speed in mountain versus lowland rivers, the relationship between animal colouration and habitat, building a correct food chain, and, similarly to third grade, a complex item on designing a birdhouse from recyclable materials.

The final tests were explicitly built around the six levels of Bloom's taxonomy, for both grades. In third grade, the items addressed, in order, identifying the class to which the butterfly and the frog belong (remembering), completing a statement about plants' needs (understanding), matching four animals to their corresponding taxonomic group (applying), analysing a situation involving a fish and a frog, identifying their habitats and common characteristics (analysing), arguing for the correctness of the statement “All animals can live in the same place” (evaluating), and planning an observation sheet for a living creature from nature, with sub-requirements covering information selection, hypothesis formulation, describing an observation plan, and explaining adaptation to the environment (creating). The maximum score on the third-grade posttest was 33 points. The final test for fourth grade followed the same six-level structure, with items on the states of water and the phenomenon of dissolving, culminating in planning an experiment on dissolving sugar in water, structured similarly to the creation item in third grade. The maximum score was likewise 33 points, and marking was carried out using a three-tier analytic scoring guide, with differentiated assessment of the correctness and complexity of responses. The tests were administered to the whole class, under identical conditions for all groups, with standardised working time.

4.5. Stages of the research

The structure of the items assessed thus reflects a deliberate progression from identification and simple explanation tasks toward tasks requiring comparison, the analysis of concrete situations, the argumentation of a position, and, finally, the autonomous design of one's own inquiry process — sub-competencies considered by the author to be relevant indicators of the investigative competency targeted by the research's fifth specific objective. The fact that each item was explicitly labelled with its corresponding Bloom level subsequently allowed for the separate statistical analysis of the six cognitive dimensions, not merely of the test's overall score.

The research was carried out in three stages. In the initial stage, the pretest was administered to both groups, simultaneously and under identical conditions, in order to determine students' initial level of preparation and to verify the comparability of the two groups. During the instructional-intervention stage, the experimental group took part in activities carried out according to the mixed model — guided individual study through video materials and work tasks, followed by applied and investigative activities in class, based on PBL and FL principles — while the control group continued to be taught through traditional methods, following the same curriculum and the same content. In the final stage, the posttest was administered to both groups, under the same standardised conditions as the pretest, with the collected data subsequently subjected to comparative statistical analysis, intended to determine student progress, performance differences between groups, and development across cognitive levels.

5. Research Results

5.1. Overall performance in the Science subject

To analyse the differences between the experimental group and the control group according to testing time, Linear Mixed Models are used, with time (pretest/posttest) and group type (experimental/control) entered as fixed effects, together with their interaction, and participant included as a random effect, in order to control for individual variation.

The model's results revealed a significant effect of group, $F(1, 259) = 74.73$, $p < 0.001$, a significant effect of time, $F(1, 259) = 382.44$, $p < 0.001$, as well as a strongly significant group-by-time interaction, $F(1, 259) = 120.97$, $p < 0.001$. This latter result shows that students' progress between pretest and posttest differed substantially by group: the estimated mean of the experimental group increased from 22.18 points at pretest to 29.94 points at posttest, while the mean of the control group increased more modestly, from 21.96 to 24.13 points. This interaction confirms the overall effectiveness of the educational intervention based on integrating FL with PBL on students' overall performance in the Science subject.

5.2. Performance across the levels of Bloom's taxonomy

For each of the six levels of Bloom's taxonomy, similar Linear Mixed Models were applied, estimated using the Restricted Maximum Likelihood method, with the significance of effects evaluated using Satterthwaite tests.

At the Knowledge level, significant effects of group, $F(1, 517) = 20.164$, $p < 0.001$, and of time, $F(1, 517) = 8.690$, $p = 0.003$, were found, but the group-by-time interaction did not reach statistical significance, $F(1, 517) = 0.531$, $p = 0.467$. Both groups showed a moderate increase in scores between pretest and posttest, with progress only slightly more pronounced in the experimental group, suggesting that the intervention did not produce a significant additional advantage at this elementary level of the taxonomy, where both methods appear equally effective.

At the Understanding level, the effect of time was strongly significant, $F(1, 259) = 102.260$, $p < 0.001$, while the main effect of group was not significant, $F(1, 259) = 0.178$, $p = 0.673$, indicating that, overall, the two groups do not differ considerably. The group-by-time interaction, however, was strongly significant, $F(1, 259) = 98.656$, $p < 0.001$: the experimental group progressed from a mean of 1.681 points at pretest to 2.610 points at posttest, while the control group remained practically stable (from 2.117 to 2.125 points) — a result suggesting a strong positive effect of the intervention on the development of students' comprehension ability.

At the Application level, neither the main effect of group, $F(1, 259) = 0.615$, $p = 0.433$, nor the effect of time, $F(1, 259) = 3.025$, $p = 0.083$, was significant overall. The group-by-time interaction was, however, significant, $F(1, 259) = 6.408$, $p = 0.012$: the experimental group progressed from 2.475 to 2.745 points, while the control group remained relatively stable, even recording a slight decrease (from 2.583 to 2.533 points) — a result indicating a positive effect of the intervention on the practical application of knowledge.

At the Analysis level, a significant effect of group was identified, $F(1, 259) = 13.361$, $p < 0.001$, with the experimental group maintaining higher scores than the control group at both pretest and posttest. However, neither the effect of time, $F(1, 259) = 0.135$, $p = 0.714$, nor the group-by-time interaction, $F(1, 259) = 0.893$, $p = 0.345$, was statistically significant, indicating that the educational intervention did not produce a further significant change in analytical competencies, relative to the difference already existing between groups from the pretest stage onward.

At the Evaluation level, the effect of group was significant, $F(1, 259) = 56.431$, $p < 0.001$, and the group-by-time interaction was also statistically significant, $F(1, 259) = 8.058$, $p = 0.005$: the experimental group increased from 2.610 to 2.752 points, while the control group decreased from 2.250 to 2.058 points — a result suggesting a positive effect of the intervention on the development of students' evaluation competencies.

The strongest effect of the intervention was identified at the Creation level, where the group-by-time interaction recorded the highest statistical value of all six levels analysed, $F(1, 259) = 166.95$, $p < 0.001$, alongside significant effects of group, $F(1, 259) = 67.81$, $p < 0.001$, and of time, $F(1, 259) = 712.15$, $p < 0.001$. The experimental group progressed from a mean of 1.640 points at pretest to 2.716 points at posttest — a considerably larger increase than that recorded by the control group, which went from 1.708 to 2.082 points.

Overall, the pattern of results across the Bloom levels confirms the research's secondary hypothesis SH2: the effects of the intervention were reduced or absent at the lower cognitive levels — knowledge and analysis, respectively, where the pre-existing difference between groups did not increase — and progressively stronger at the higher levels — understanding, application, evaluation, and, especially, creation, the level at which the largest interaction effect among all six dimensions analysed was recorded.

5.3. Differences between third grade and fourth grade

The analysis of overall performance, with the “grade” variable introduced into the model, confirmed the already-identified significant effects of group, $F(1, 257) = 74.777$, $p < 0.001$, of time, $F(1, 257) = 381.647$, $p < 0.001$, and of the group-by-time interaction, $F(1, 257) = 121.708$, $p < 0.001$. The main effect of grade was not significant, $F(1, 257) = 0.757$, $p = 0.385$, and the triple group-by-time-by-grade interaction did not reach the threshold of statistical significance, $F(1, 257) = 2.937$, $p = 0.088$, indicating a relatively similar intervention effect at both school levels, even though some differences in magnitude can be observed: in third grade, the experimental group progressed from 21.94 to 29.33 points, and in fourth grade, from 22.40 to 30.53 points, both increases being clearly higher than those recorded by the corresponding control groups.

At the level of the individual dimensions of Bloom's taxonomy, the pattern of results is more nuanced. At the Knowledge level, the effect of group remained significant, $F(1, 256.43) = 20.986$, $p < 0.001$, as did the effect of time, $F(1, 256.41) = 8.729$, $p = 0.003$, while the main effect of grade was not significant, $F(1, 256.43) = 0.008$, $p = 0.927$. Analysis by grade, however, shows a different pattern: in third grade, the control group progressed considerably (from 2.355

to 2.918 points), approaching the level of the experimental group, while in fourth grade the control group actually recorded a decrease in scores (from 2.810 to 2.552 points), with the experimental group remaining relatively stable at both grade levels.

At the Understanding level, significant effects of time were found, $F(1, 257) = 109.432$, $p < 0.001$, and of grade, $F(1, 257) = 15.336$, $p < 0.001$, as well as a significant group-by-time interaction, $F(1, 257) = 109.041$, $p < 0.001$. The group-by-grade interaction, $F(1, 257) = 24.393$, $p < 0.001$, and the time-by-grade interaction, $F(1, 257) = 22.349$, $p < 0.001$, were also significant, but the triple group-by-time-by-grade interaction did not reach the threshold of significance, $F(1, 257) = 0.097$, $p = 0.756$, leading to the conclusion that the effect of the intervention on understanding was similar at the two school levels, although the absolute progress was more pronounced in third grade.

At the Application level, the group-by-grade interaction was significant, $F(1, 257) = 14.694$, $p < 0.001$, but the triple interaction was not significant, $F(1, 257) = 0.552$, $p = 0.458$, suggesting a relatively constant effect of the intervention between the two grades. At the Analysis level, significant effects of grade were found, $F(1, 257) = 5.593$, $p = 0.019$, and a significant group-by-grade interaction, $F(1, 257) = 10.884$, $p = 0.001$; the group-by-time interaction, however, remained non-significant, $F(1, 257) = 0.889$, $p = 0.347$, confirming, at the level of the by-grade analysis as well, the absence of an intervention effect on this cognitive dimension.

At the Evaluation level, significant effects of grade were found, $F(1, 257) = 32.496$, $p < 0.001$, and of the time-by-grade interaction, $F(1, 257) = 15.789$, $p < 0.001$, but the triple group-by-time-by-grade interaction was not significant, $F(1, 257) = 0.193$, $p = 0.661$, indicating a relatively homogeneous effect of the intervention. At the Creation level, the effect of grade was significant, $F(1, 257) = 15.849$, $p < 0.001$, but the group-by-grade ($p = 0.563$), time-by-grade ($p = 0.185$), and triple ($p = 0.079$) interactions did not reach the threshold of significance, confirming that the substantial effect of the intervention on creativity was manifested consistently in both grades: in third grade, the experimental group increased from 1.604 to 2.596 points, and in fourth grade, from 1.674 to 2.832 points.

It is worth noting that, for several of the Bloom dimensions analysed by grade, significant group-by-grade interactions appear in the absence of a significant triple group-by-time-by-grade interaction: the difference between the experimental and control groups varies somewhat in magnitude between the two grades, but the change between pretest and posttest — the actual effect of the intervention — remains, according to the results reported by the author, comparable between the two school levels.

In conclusion, with the exception of the Knowledge dimension, the only one at which the effect of the intervention differed significantly between the two school levels, the impact of the integrated instructional model was, overall, consistent between third grade and fourth grade, since the triple group-by-time-by-grade interaction was not significant for most of the dimensions investigated. This result provides an additional argument in favour of the model's broad applicability across the entire primary cycle.

6. Discussion

The research results confirm the effectiveness of the integrated instructional model, based on combining Flipped Learning with Project-Based Learning, in teaching the Natural Science subject in primary education. Students in the experimental group achieved superior performance, both in overall performance and across most of the cognitive dimensions assessed with reference to Bloom's revised taxonomy, thereby supporting the research's general hypothesis and the relevance of integrating the two pedagogical models into a unitary instructional approach.

This effectiveness of the mixed model is thus explained by the functional complementarity between the two components. Flipped Learning transfers introductory activities and basic cognitive processes to the student's individual space, freeing up class time for application, inquiry, collaboration, and reflection activities (Bergmann & Sams, 2012; Persky & McLaughlin, 2017), while Project-Based Learning provides the authentic framework through which knowledge is used to solve problems, create products, and develop higher-order competencies (Thomas, 2000; Larmer et al., 2015; Kokotsaki et al., 2016). The cognitive complementarity of the two models is further confirmed by the differentiated distribution of activities across the levels of Bloom's taxonomy, where the Flipped Learning component specifically supports remembering and understanding, while the Project-Based Learning component uses class time for applying, analysing, evaluating, and creating.

The differentiated profile of results across Bloom levels — reduced or absent differences at the lower levels, progressively more consistent at the higher levels — confirms the theoretical prediction formulated by the author and is consistent with the specialised literature. Hmelo-Silver (2004) shows that project-based learning particularly fosters the development of higher-order thinking and knowledge transfer, and Wiggins and McTighe (2005) point out that deep understanding is reflected in students' ability to apply, analyse, evaluate, and use knowledge in new contexts. The results obtained support these theoretical perspectives, with active, investigative strategies producing stronger effects on complex cognitive processes than on simple memorisation or recall of information.

The research results confirm this theoretical prediction: the differences between the experimental and control groups are smaller at the lower levels of the taxonomy and become progressively more consistent at the higher cognitive levels, and this cognitive profile of the results is consistent with the pedagogical logic of the integrated model, supporting the idea that active, investigative strategies produce stronger effects on complex cognitive processes than on the simple memorisation or recall of information.

The significant differences identified at the analysis, evaluation, and creation levels are explained by the specific nature of the project and inquiry activities, which involved formulating questions, testing hypotheses, interpreting results, and creating authentic products, thereby stimulating complex cognitive processes and the active use of knowledge. Larmer et al. (2015), Kokotsaki et al. (2016), and Krajcik and Czerniak (2018) show, in this regard, that authentic projects involve sustained inquiry, collaboration, reflection, and problem-solving in real contexts, characteristics that are found in the structure of the activities carried out within the intervention.

The research results are also interpreted from a socio-constructivist perspective: both PBL and FL draw on learning through interaction, collaboration, and cognitive scaffolding. The activities carried out within the intervention created contexts in which students collaborated, discussed solutions, negotiated meanings, and jointly constructed answers and products, with the teacher's role not limited to transmitting information but including organising learning experiences, providing cognitive support, and facilitating inquiry and reflection processes.

This observation is particularly relevant when compared with the results obtained at the Analysis and Knowledge levels, where, as shown, the intervention did not produce a further significant change. The contrast between the two categories of Bloom levels — those at which the intervention had an effect and those at which it did not — is the central element in interpreting the results, as it confirms, point by point, the research's secondary hypothesis SH2 and provides an argument for the idea that the integrated model acts selectively, on the cognitive processes it explicitly targets through its five-stage structure, rather than through a general, undifferentiated “activation” effect on students.

It is also worth noting that the effects of the integrated model were manifested both in third grade and in fourth grade, with the absence of significant differences for most of the interactions among group, time, and school level suggesting the consistency of the intervention's effect across different curricular contexts within primary education and supporting the possibility of using the model in other, similar educational contexts, with adaptation to the particularities of the content and age level.

From the perspective of the national curriculum for the Natural Science subject, which places emphasis on exploration, inquiry, application, and the creation of simple products, the research results suggest that the integrated instructional model facilitates precisely the development of these competencies, contributing to reducing the gap between the competencies set out in the curriculum and traditional practices, predominantly centred on transmitting information. Last but not least, the accessible nature of the proposed model and the possibility of implementing it without complex material resources are emphasised, with the inquiry activities and projects used within the intervention carried out using accessible materials, adapted to the ordinary school context — an aspect that supports the possibility of using the model in educational contexts with limited resources as well.

7. Limitations of the Research

A number of methodological and contextual limitations of the experimental research are identified, which must be taken into account when interpreting the results. A first limitation is the quasi-experimental nature of the design and the absence of individual randomisation of participants into research groups. Although the experimental and control groups were comparable at the pretest stage, the influence of external variables specific to the educational context or to students' individual characteristics cannot be completely ruled out, even though carrying out the research in real school settings gives the results a high degree of ecological validity.

A second limitation is the possible bias associated with the dual role of the practitioner-researcher: their involvement in designing and monitoring the intervention allowed for ensuring the fidelity of the instructional model's implementation, but may, at the same time, have influenced participants' behaviour and the conduct of instructional activities. The research also presents limitations related to the assessment instruments used: the pretests and posttests differ partly in structure, maximum score, and content assessed. Although this limitation was mitigated through the use of percentage scores and the separate analysis of Bloom levels, part of the observed progress may also reflect students' growing familiarity with the specific content of the units studied.

Participation in an intervention perceived as different from usual activities may also generate the Hawthorne effect, namely increased performance as a result of the additional attention given to participants. Nevertheless, the differentiated profile of the effects observed across the levels of Bloom's taxonomy — reduced effects at the lower levels and strong effects at the higher levels — suggests that the results cannot be explained solely by a general increase in motivation. Finally, the research results must be interpreted in relation to the specific nature of the sample investigated: the research was carried out on a sample of students from urban settings and in relation to certain curricular units and specific educational resources, which limits the possibility of automatically generalising the results to significantly different educational contexts.

8. Conclusions of Chapter III

The results presented support the effectiveness of the integrated instructional model, based on combining Flipped Learning with Project-Based Learning, in teaching the Natural Science subject in primary education. The proposed model contributed to improving students' school performance and to developing higher-order cognitive competencies, particularly with regard to application, analysis, evaluation, and creation, confirming that active, investigative instructional strategies foster the development of deep learning and support the transfer of knowledge to authentic contexts. Integrating Flipped Learning into project activities allowed for the reorganisation of instructional time and the use of class time for inquiry, collaboration, experimentation, and reflection, with students actively engaged in the process of constructing knowledge and given the opportunity to use information in relevant, applied contexts. The research results also highlight the important role of experimental and inquiry activities in developing competencies specific to the field of Science: students' participation in exploration and inquiry activities contributed to the development of critical thinking, autonomy, and the ability to formulate and argue for solutions. Overall, Chapter III supports the need to orient the educational process toward pedagogical models that draw on students' active engagement, collaboration, reflection, and inquiry, moving beyond the traditional paradigm predominantly centred on the transmission and reproduction of information, and the proposed integrated instructional model is presented as a relevant pedagogical alternative for teaching Science in primary education, offering theoretical and empirical arguments for the coherent integration of the two pedagogical models into instructional practice.

CHAPTER IV. GENERAL CONCLUSIONS AND DISCUSSION

1. General Conclusions of the Thesis

The experimental research aimed to evaluate the effectiveness of an integrated mixed instructional model — combining flipped learning (Bergmann & Sams, 2012) with project-based learning (Thomas, 2000) — against the traditional teaching model, in the subject of Natural Science, in third and fourth grade, and was carried out on a sample of 261 students with valid data (141 in the experimental group, 120 in the control group), distributed across 12 urban classes, across two content units run in parallel: Life Science, in third grade, and Bodies and Properties, in fourth grade.

1.1. Synthesis of the preliminary research

Chapter IV integrates the conclusions of four preliminary studies, which progressively grounded the experimental research described in Chapter III. The thesis's research process was structured progressively, starting with an analysis of the theoretical foundations of Project-Based Learning and Flipped Learning, continuing with an investigation of teachers' perceptions, and concluding with the experimental validation of the integrated instructional model.

The analysis of the specialised literature highlighted important pedagogical convergences between the two educational models: both PBL and FL are grounded in constructivist and socio-constructivist learning principles, promote students' active engagement in the process of constructing knowledge, and support the development of higher-order competencies. Their complementarity is supported by the distribution of learning activities across the levels of Bloom's revised taxonomy: Flipped Learning facilitates students' access to introductory content and to lower cognitive processes outside of class, allowing more room during face-to-face activities for application, analysis, evaluation, and creation — dimensions specifically drawn upon through project and inquiry activities.

The first preliminary study showed that primary school teachers use, in parallel, both strategies specific to deep learning — with an emphasis on understanding, reflection, and the integration of information — and strategies such as planning, analysis, self-regulation, and monitoring of learning, aimed at understanding the meaning of content and at making connections between ideas and different fields of knowledge. The results also showed that these deep-learning strategies are used in parallel with certain surface-learning strategies, suggesting that extrinsic motivation and an orientation toward academic performance and assessment remain important elements in how learning is approached.

The second study investigated the attitudes of preschool and primary school teachers toward experiments and demonstrative experimental activities, examining the perceived value and usefulness of this type of activity, as well as teachers' motivation and confidence to implement them in class. Although the specialised literature reports differences in teachers' attitudes toward experimental activities depending on teaching experience and educational background (Vlachos et al., 2024), the present study did not find such significant differences based on teaching grade or professional experience. The results showed that teachers hold positive attitudes toward experiments, attributing high value to them and being motivated to use them in teaching; however, their confidence in their own ability to implement experiments and demonstrative experimental activities was considerably lower compared with the reported value and motivation, suggesting difficulties or uncertainty regarding the concrete implementation of this type of activity.

The third preliminary study aimed to identify the perceptions of primary and preschool teachers and pre-service teachers regarding the implementation of Project-Based Learning, through the analysis of the instructional practices used, of student engagement in PBL activities, and of the perceived benefits of this approach, as well as exploring the relationship between these dimensions and conceptions of experimental research. The results showed predominantly positive perceptions of PBL implementation in class, revealing significant positive relationships among PBL-specific instructional practices, student engagement, and the perceived benefits of this approach, thus confirming the interdependence among these dimensions (Zhang & Ma, 2023; Rehman et al., 2024). Teachers with more favourable perceptions of PBL also showed more developed conceptions regarding the processes of scientific inquiry and knowledge construction.

The fourth preliminary study, methodologically mixed in nature, identified teachers' perceptions of PBL implementation, of the competencies required of students in order to carry out project activities, and of the role of reflection, assessment, and metacognition in the educational process. The thematic analysis of the open-ended responses, carried out using MAXQDA software, showed that Project-Based Learning is perceived by teachers as a complex, effective educational approach for developing students' competencies, with teachers emphasising the importance of collaboration, activity organisation, and the development of critical thinking, as well as the link between PBL, students' active and authentic engagement, and deep understanding of content.

The four preliminary studies therefore did not have a merely descriptive role, but functioned as successive stages in refining the research problem: from the general observation of the coexistence of deep- and surface-learning strategies in instructional practice, to the identification of a specific gap — between the value attributed to experiments and confidence in the ability to implement them — then to exploring perceptions of PBL as a possible solution to this gap, and finally to an in-depth qualitative analysis of the conditions and competencies required for its implementation. This argumentative trajectory explains why the model tested experimentally in Chapter III is not a simple theoretical combination of FL with PBL, but a response built progressively around concrete difficulties, reported directly by teachers in the field.

Nevertheless, these preliminary studies also revealed the existence of concrete difficulties related to the practical implementation of such approaches, particularly with regard to organising inquiry activities, managing projects, and using experimentation in day-to-day instructional activity. This shaped the need to develop a mixed model integrating Flipped Learning with Project-Based Learning, able to effectively support teachers in designing Natural Science lessons — a need which led to the design and experimental validation of the model described in Chapter III.

1.2. Theoretical implications

From a theoretical perspective, the research contributes to extending the conceptual framework regarding the use of active, constructivist pedagogical approaches in primary education, through the analysis of the convergences between Project-Based Learning and Flipped Learning and through the grounding of an integrated instructional model. The results support the idea that the effectiveness of student-centred strategies does not derive solely from the active nature of the activities carried out, but from the way in which they are pedagogically structured and supported through guidance, scaffolding, and appropriate cognitive organisation, confirming the relevance of socio-constructivist perspectives on learning, according to which knowledge is built through interaction, collaboration, and active engagement in solving authentic problems.

The research highlights that Flipped Learning and Project-Based Learning should not be regarded as independent pedagogical models, but as complementary approaches that mutually support each other: Flipped Learning creates the conditions necessary for reorganising instructional time and for differentiated access to content, while Project-Based Learning uses the class time thus freed up for collaborative, investigative, and applied activities. The research results also support the relevance of Bloom's revised taxonomy as a conceptual tool for designing and analysing learning activities (Anderson & Krathwohl, 2001), with the differences identified between cognitive levels confirming that active instructional strategies produce more consistent effects on higher-order competencies compared with strategies predominantly centred on reproducing information.

Last but not least, the research contributes to the literature on Science didactics in primary education, by highlighting the role of inquiry and experimental activities in developing students' cognitive and metacognitive competencies, supporting the idea that learning Science becomes more effective when students are engaged in activities involving exploration, hypothesis formulation, experimentation, and argumentation.

1.3. Implications for pedagogical practice

The research results have relevant implications for the design and conduct of instructional activities in primary education. Firstly, the research highlights the need to reorganise teaching activities in the sense of using class time for applied, collaborative, and investigative activities, with the integration of Flipped Learning allowing part of introductory instruction to be transferred outside the classroom and creating conditions for students' active engagement in problem-solving, experimentation, and project creation.

Secondly, the results support the need to develop teachers' methodological competencies regarding the organisation and coordination of experimental and project activities, given that the preliminary studies showed that teachers value these strategies but encounter difficulties in implementing them in practice. In this context, initial and continuous training programmes should include concrete examples of designing and implementing inquiry activities and interdisciplinary projects, as well as educational resources adapted to the specific nature of the two models — digital materials, methodological guides, examples of experimental activities, and instruments for assessing complex competencies.

Another important aspect concerns assessment: the research results support the importance of using assessment methods that go beyond the level of reproducing information and that allow for the assessment of application, analysis, argumentation, and reflection, with the assessment of project activities and investigative competencies requiring varied instruments, capable of capturing both the final product and the learning process. The research results also highlight the importance of building an educational climate that supports collaboration, autonomy, and students' active engagement, with project and inquiry activities fostering the development of responsibility for one's own learning and contributing to the development of intrinsic motivation and a sense of competence.

1.4. Original contributions of the research

The originality of the research lies both in the theoretical grounding of an integrated instructional model and in the experimental validation of its effectiveness in the context of primary education. From a theoretical perspective, the research contributes to clarifying the pedagogical convergences between Project-Based Learning and Flipped Learning and to highlighting how the two models complement each other in supporting deep learning.

From a methodological perspective, the research proposes an integrated instructional model, structured in five stages, adapted to the specific nature of the Natural Science subject and to the particularities of primary school students, providing a structured framework for organising project, inquiry, and experimentation activities by drawing on the principles of

Flipped Learning. From a practical perspective, the research offers concrete examples of designing and implementing integrated instructional activities, experimentally validated on a large sample of 261 students, as well as instruments and resources useful to teachers interested in using active, investigative strategies in teaching Science.

The original contributions of the research can accordingly be summarised on three complementary levels: a conceptual level, at which the complementary — rather than competing — relationship between the two pedagogical models is clarified; a methodological level, materialised in the five-stage instructional model, with a timing protocol and explicit mechanisms for ensuring implementation fidelity; and an empirical level, given by the validation of this model on a large sample, through rigorous statistical methods (linear mixed models), which allow the effect of the intervention to be separated from individual variation among students and from pre-existing differences between groups.

The results obtained support the idea that the coherent integration of Project-Based Learning and Flipped Learning may represent a viable direction for modernising instructional practices in primary education, contributing to the development of authentic, relevant, and formative learning experiences for students, within a coherent, flexible pedagogical framework capable of responding to the demands of contemporary education.

2. General Limitations of the Research and Directions for Future Research

Any educational research carried out in real school settings involves a series of methodological and contextual constraints that may influence the interpretation and generalisation of results. In addition to the limitations already discussed in relation to the experimental research — the quasi-experimental nature of the design, the absence of randomisation, the involvement of the practitioner-researcher in designing and coordinating the intervention, the possible Hawthorne effect, and the existing differences between the structure and content of the pretests and posttests — there is, at the level of the thesis as a whole, the difficulty of fully capturing, through standardised instruments, complex processes such as reflection, knowledge transfer, or creativity.

The research results must also be interpreted in relation to the specific nature of the sample investigated: the research was carried out on a sample of primary school students, coming predominantly from urban settings and using certain specific curricular resources and instructional materials, so that generalising the results to other school levels, other subjects, or significantly different educational contexts must be done with caution.

These limitations also open up important directions for future research. A first direction would be extending the research over longer periods of time, in order to analyse the stability of the effects of the integrated instructional model and its impact on the development of competencies over the long term, beyond the relatively short duration of the intervention (6 and 9 weeks, respectively). It would also be relevant to investigate the effectiveness of the model in other school subjects or at other levels of education, given that the present research was limited to the Natural Science subject, in third and fourth grade.

Future research could also examine, in greater depth, the relationship between the use of Flipped Learning and the development of self-regulation in learning, intrinsic motivation, and students' socio-emotional competencies. It would also be useful to investigate how different forms of pedagogical scaffolding, types of digital resources, or ways of organising project activities influence the effectiveness of the integrated instructional model. Last but not least, a relevant research direction concerns the analysis of teachers' experiences and perceptions regarding the integrated implementation of Project-Based Learning and Flipped Learning, as well as identifying the difficulties and conditions necessary for the sustainable implementation of such pedagogical models in current educational practice.

3. Final Conclusion

Overall, the research presented in Chapters III and IV of the doctoral thesis confirms that the coherent integration of Flipped Learning with Project-Based Learning represents a viable direction for modernising instructional practice in the Natural Science subject, in primary education. The empirical data, obtained on a large sample of 261 students, through a rigorous quasi-experimental design and a statistical analysis based on linear mixed models, support the general hypothesis of the research and reveal particularly strong effects of the intervention on the higher cognitive levels of Bloom's taxonomy — especially on creation, evaluation, and understanding competencies — while at the lower cognitive levels (knowledge, analysis) the differences between the experimental group and the control group were small or mainly reflected pre-existing differences.

The results provide both a theoretical foundation and practical arguments for orienting the educational process toward pedagogical models that draw on students' active engagement, collaboration, inquiry, and reflection, moving beyond the traditional paradigm predominantly centred on the transmission and reproduction of information. The integrated instructional model, structured around the five stages described in the research, represents a relevant and accessible pedagogical alternative for teaching Science in primary education, with potential for extension to other subjects and levels of education, depending on the adaptations required by age and content particularities.

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