Examining the advantages and limitations of implementing cross-circular links within the Leaving Certificate subjects Biology and Chemistry.

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Examining the advantages and limitations of implementing cross-circular links within the Leaving Certificate subjects Biology and Chemistry.

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Dissertation submitted in partial fulfilment of the award of

Professional Master of Education in Post-Primary

Date: June 2024

Abstract

This thesis explores the impact of cross-curricular links on advantages and disadvantages, focusing specifically on the Leaving Certificate subjects of Biology and Chemistry. The study assesses the advantages and limitations of implementing such integrative approaches within the Irish education system. Employing an interpretive paradigm, the research adopts a qualitative methodology, utilising five semi-structured interviews to gather in-depth insights from educators experienced in teaching the relative subjects. Thematic analysis is used to analyse the data, revealing key themes and patterns regarding the effectiveness of cross-curricular links. Findings suggest that while cross-curricular integration can enhance understanding and retention of complex scientific concepts, it also presents challenges such as time constraints and curriculum planning. The study concludes with recommendations for optimising cross-curricular strategies to improve academic outcomes in the sciences.

Acknowledgements

I am deeply grateful to everyone who supported me in completing this research project. I want to express my thanks to the interview participants and everyone who offered their time and assistance throughout the research dissertation. I am thankful to my thesis supervisor for their commitment to my success during my professional master's program. I would also like to acknowledge the unwavering support and belief in me from my family, especially my parents and partner, which has kept my spirits and motivation high during this process.

Table of Contents

List of Figures

List of Acronyms and Abbreviations

STEM – Science, technology, engineering and mathematics

CCL – Cross-circular links

CPD – Continuous professional development

NCCA – National Council for Curriculum and Assessment

Chapter One

Introduction

1.1 Origin of the Dissertation

In recent decades, there has been an increase in science, technology, engineering and mathematics (STEM) job vacancies resulting in educational interest in post-primary STEM education in Ireland. According to the Central Statistics Office (2019), Ireland had the highest number of STEM graduates in the European Union in 2018, with a rate of 35.2 per 1,000 individuals aged 20-29. School communities play a significant role in developing positive attitudes towards STEM, particularly for young adolescents. Teachers have the opportunity to connect what students learn in class with their future career paths; methodologies such as cross-circular links (CCL) between various STEM subjects could aid in establishing a strong foundation in STEM education.

In the past, experts such as Hadow (1931) and Plowden (1967) acknowledged that real-life challenges require the integration of various disciplines and skills. Throughout SEPP1 placement, the researcher gained a profound appreciation for the value of integrating different fields of study. During placement, the researcher and their tutor prioritised incorporating at least one cross-disciplinary link in each lesson plan as they delved into the intricacies of Biology and Chemistry.

White and Delaney (2021) noted that teachers face the challenge of incorporating interdisciplinary learning into STEM education due to its practical nature and diverse curricular components. As such, this study explores the advantages and limitations of implementing CCL within the Leaving Certificate subjects of Biology and Chemistry.

1.2 Background to the Project

This document aims to develop further the STEM integration research paradigm introduced by Moore et al. (2010) and Wang et al. (2011). STEM integration refers to combining science, technology, engineering, and mathematics disciplines to enhance students' comprehension of each subject by connecting concepts, expanding their knowledge of STEM fields, and sparking their interest in STEM. The research aimed to gain insight into implementing CCL and their potential impact on the Leaving Certificate Biology and Chemistry. The researcher picked the topic based on their personal and occupational experiences, SEPP1 experience, and guidance from their tutor. This topic will allow the researcher to expand their content knowledge beyond the fundamental principles.

1.3 Rationale

Interdisciplinary learning fosters a deeper understanding of the subject matter by encouraging students to reflect critically on new ideas or issues from multiple perspectives. According to Dewey's perspective in Democracy and Education (1916), which rejects a ranking of educational values and supports a diversity of disciplines, interdisciplinary learning can be advantageous for secondary students in Ireland. The definition of interdisciplinary learning is debated due to its varying interpretations (Ralston, 2011). This study aims to narrowly focus on interdisciplinary learning within the Leaving Certificate subjects of Biology and Chemistry and their cross-circular linkage. Any potential publications resulting from this research could benefit the skills of the researcher and other teachers in their practice.

1.4 Dissertation Layout

Chapter 2 describes the current understanding of the epistemology of CCL in education and within the sciences and its advantages and limitations. The chapter's main focus is discovering current research in this area. In Chapter 3, the research process is thoroughly explained and justified, covering important aspects such as the methodology and chosen research methods. Chapter 4 presents the findings of the research. This lays the foundation for Chapter 5, which is dedicated to providing a comprehensive and insightful interpretation of the findings from Chapter 4. In Chapter 6, the key takeaways from the findings of the previous chapters are summarised and discussed.

1.5 Conclusion

The primary goal of this thesis is to add to the existing knowledge on interdisciplinary learning and its application in STEM education. Specifically, it focuses on Biology and Chemistry in the Leaving Certificate curriculum. The expected outcomes of this research are to improve the researcher's teaching abilities and offer beneficial insights to other educators. By integrating current research and connecting different disciplines to develop a better understanding of STEM topics, this study has the potential to positively impact STEM education in Ireland and worldwide. To embark on a comprehensive exploration of interdisciplinary learning and its implications for STEM education, the literature review in Chapter 2 will delve into the current epistemological understanding of CCL, examining their advantages and limitations within educational contexts and the sciences.

Chapter Two

Literature Review

2.1 Introduction

In Ireland, students are presented with a range of Leaving Certificate subjects to choose from, including Biology and Chemistry. Notably, there has been a 3.6% increase in students enrolled in chemistry between 2012 and 2017. However, in 2017, the Department of Education and Skills found Biology to be the subject of choice among female students, with a substantial participation rate of nearly 60% (Department of Education and Skills, 2017). As STEM subjects continue to gain momentum in the classroom, researchers are exploring effective teaching strategies in STEM education (Lo, 2021; Hsu and Fang, 2019; McDonald, 2016). Many theories have been proposed on the effectiveness of CCL within education. Although the literature covers various theories, this review will focus on CCL within the sciences, specifically Biology and chemistry in Ireland, while drawing global research into some themes. This research explores the challenge of defining CCL, including its role in educational theory, curriculum development, and CCL's current role. It also assesses the challenges and advantages of CCL, where CCL exists in the current Biology and Chemistry curriculum and future works in the field. Although the literature presents these themes in various contexts, this paper will primarily focus on their application to the use of CCL at the Leaving Certificate level within Biology and chemistry in Ireland.

2.2 The Role of Cross-Curricular Learning in STEM

Recently, there has been increased attention paid to CCL and its significance. This area of research focuses on developing connections beyond the confines of traditional curriculums.

The STEM Education 2020: Reporting on Practice in Early Learning and Care, Primary and Post-Primary Contexts report highlighted this challenge within the Irish education system, recognising that teachers assigned to teach STEM subjects are continuously growing highly specialised and qualified in their respective areas. This may be partially due to the geneses of the Teaching Council. The council's guidance has been pivotal in ensuring the quality of preparation for newly qualified teachers, particularly in specialised fields such as the sciences (Department of Education and Skills, 2020). In contrast to the Department of Education and Skills (2017), some countries such as the USA (Archer et al., 2013), the UK (Means et al., 2017) and Australia (Commonwealth Australia, 2017) are experiencing significant declines in the proportion of students selecting senior science subjects in the last two decades. While Ireland's data is currently more positive, the importance of science and other STEM-related literacies has been emphasised worldwide (Cooper and Berry, 2020) to ensure students' occupational choices are meeting the increase in professional, scientific and healthcare roles highlighted by Hobbs, Clark and Plant (2018). According to the Central Statistics Office's 2017 report Measuring Ireland's Progress, Ireland has the second-highest number of STEM graduates. Although this is a favourable position, it is important for the Irish education system to continually learn from other countries' efforts to increase STEM education. By incorporating these strategies, such as CCL, Ireland can continue to secure a future as a strong STEM country.

2.3 Exploring the Evolution and Definitions of Cross-Curricular Learning

The review initially focused on research from 2015 to 2023; the search was then broadened to include prior years to gather enough relevant research papers. The search was limited to databases with English-written content, specifically targeting post-primary school-level studies related to CCL. During the initial search for "cross-curricular," it became apparent that interchangeable terms such as interdisciplinary/multi-disciplinary and cross-curricular were used in the literature. Barnes' (2015, p.273) "An Introduction to Cross-Curricular Learning" provides clear definitions and categories of cross-curricular learning, including tokenistic, hierarchical, multidisciplinary, interdisciplinary, opportunistic, and double focus. While these definitions help to understand the various types of cross-curricular learning, they may not encompass all research. Wang et al. (2011) observe that integration is frequently referred to as "multidisciplinary" or "interdisciplinary" in academic literature.

They explain that the interdisciplinary approach blurs the lines between subjects, much like a "melting pot," while the multidisciplinary approach emphasises the clear identification of each subject. This differs from Barnes' (2015) perspective, as he contends that cross-curricular learning is given equal weight in the multidisciplinary approach, while the interdisciplinary approach seeks to connect or blend subjects imaginatively. Ralston (2011, p.310) notes that defining interdisciplinarity can be difficult. However, he outlines its objectives as connecting academic fields, subfields, or schools of thought and involving diverse individuals, including teachers, students, researchers, professionals, and technology. The ultimate goal is to gain a more comprehensive perspective by breaking down traditional academic boundaries and enhancing research or teaching. This aligns with Jacob's (1989) definition of cross-curricular integration, which involves consciously applying knowledge, principles, and values to multiple academic disciplines.

The concept of cross-curricular education is ambiguous, leading to investigations across academic domains. In delving into post-primary education, the inclusive analysis evaluated secondary schools, high schools, and middle schools as conceivable alternatives. Notwithstanding, the scrutiny of extant scholarly literature unveiled a lack of discourse explicitly addressing empirically substantiated methodologies within the context of post-primary education or its analogues. As a result, the scope of the inquiry was expanded to encompass insights from primary educational institutions. Intriguingly, the findings of this exploration exhibit a unity with the observations made by White and Delaney (2021), wherein the challenge confronted by numerous educators in discerning the optimal pedagogical approaches for their classrooms is underscored. Interdisciplinary studies may be considered a new area within educational research. Gaff (1989) believes this recent interest is a resurgence where interdisciplinary learning can be noted as far back as Pythagoras's idea of the unity of knowledge (Ross, 1925). In a more contemporary context, particularly within the 19th century, Arthur Bentley subscribed to the notion that interdisciplinarity assumed the form of a methodological framework for investigative pursuits. This entailed strategically utilising diverse approaches analogous to instruments within a metaphorical "laboratory," thus facilitating exhaustive scrutiny of phenomena from diverse perspectives (Ratner et al., 1965). In contradistinction, Weber maintained that specialising within a specific domain and contributing original insights was aligned with an overarching ideal grounded in loftier spiritual principles. Consequently, this perspective engendered a decidedly unfavourable perception of interdisciplinarity. In contradistinction to Weber's perspective, John Dewey posits a case for the implementation of interdisciplinary pedagogy, advocating that the educational paradigm should eschew the isolation of scientific inquiry into the natural world from the domain of literature, rather advocating for a process of symbiotic enrichment (Dewey, 1916). More contemporaneously, Cumiskey (2022) underscores the notion that the fortification of proficiencies across diverse subjects within the comprehensive curriculum serves to substantiate Dewey's antecedent educational postulations: learners accrue not solely within the confines of the classroom environment but throughout the trajectory of their lifespans.

2.4 Advocating for Integrated Pedagogy: Challenges and Opportunities in the Irish Educational Context

Advocating for an integrated teaching approach is a justifiable proposition regarding curriculum development. However, within the Irish educational context, there is a tendency to compartmentalise subjects in the post-primary curriculum (Johnston et al., 2014). Despite a global trend towards cross-curricular or interdisciplinary approaches, as evident in 49 studies from 28 countries analysed in a review conducted by Taylor et al. in 2019, this paradigm does not seem to be reflected in the structure of the Irish Leaving Certificate Science Curriculums.

Connolly, Carr, and Knox (2023) concur with Kelly's (2009) assertion that a curriculum should not merely constitute a collection of discrete subjects. They argue that perceiving the curriculum solely as a syllabus has adverse implications for student development and societal progress. As Kind (2013) underscores in an NCCA (National Council for Curriculum and Assessment) document titled 'Review of Leaving Certificates in Physics, Chemistry, and Biology,' the current emphasis on literacy is integrated into the Senior Cycle, establishing connections between literacy and the sciences (NCCA, 2013). This implies that while these connections are valued within literacy, they remain underrepresented within the sciences. According to the Irish Primary Principles Network (2017), reviewing and revising Leaving Certificate syllabi is protracted. For instance, the revision of syllabi for Chemistry and Biology, initiated in 2007, has yet to be completed. Despite the negative perceptions surrounding this process, the NCCA intends to shift its focus from knowledge acquisition to skill development, aiming to incorporate essential skills into teaching individual senior cycle subjects (NCCA, 2010), potentially fostering cross-curricular connections. Current instances of CCL are observable within the LCA and transition year programs. The LCA, introduced in 1995, combines general education, vocational education, and vocational preparation courses, adopting a cross-curricular approach rather than a subject-based framework (Irish Primary Principles Network, 2017). Similarly, the guidelines for Transition Year stipulate that "An interdisciplinary approach would help to create that unified perspective which is lacking in the traditional compartmentalised teaching of individual subjects" (DES, 1994).

As previously mentioned, other nations are also embracing cross-curricular learning approaches. Taylor et al. (2019) researched other countries' stances on CCL, such as Scotland and the UK (Manchester). They found that the Scottish Government (2008) contends that revisiting concepts or skills from diverse perspectives enhances understanding and contributes to a more coherent and meaningful curriculum for learners, a concept implemented in some learning streams. In parallel, in the primary school setting in Manchester, a longitudinal study was conducted using curriculum data collected over a decade from a nationally representative sample of primary schools. These two cases emphasise an increased focus on enhancing the effectiveness of educational policies, which opens up opportunities for cross-curricular integration and allocates more time to these subjects (Taylor et al., 2019).

The emphasis on cross-curricular learning and interconnections is conspicuous in international research and curriculum development. However, a noticeable gap exists in the secondary education domain, particularly when compared to primary and tertiary education (White and Delaney, 2021). Specifically, concerning the sciences, You, Delgado, and DeAtley (2021) address the lack of empirical investigations that have delved into the interdisciplinary comprehension of experts from diverse science backgrounds, which could provide valuable insights for shaping current science standards and curricula. Furthermore, White and Delaney (2021) underscore the absence of empirically substantiated guidelines for educators seeking to harmonise STEM disciplines, including Biology and Chemistry, in their teaching practices alongside existing pedagogical approaches. Hasni, Lenoir, and Alessandra (2015) point out that the integrated STEM field often advances sweeping claims without a commensurate body of evidence to support them, thereby underscoring the necessity for further research in this domain. Wang et al. (2011), in drawing upon the experiences of classroom instructors, illuminate the formidable challenges associated with implementing an integrated educational approach. In practical terms, educators accustomed to conventional teaching methods may find themselves inadequately prepared to embrace the holistic ethos of integrated STEM (El-Deghaidy et al., 2017; Hasni et al., 2015; Wells, 2011). In a parallel vein, albeit within the context of primary education, Cumiskey (2022) has observed that integration can invite criticism for its potential to blur the boundaries between subjects, potentially reducing them to a singular, all-encompassing entity. This perspective may not neatly transpose to the sciences, particularly Chemistry and Biology, as their curricular content either exhibits substantial overlaps or lacks distinct demarcations. Hayes (2010) has ascertained that incorporating multiple subjects into education can yield a more well-rounded learning experience. In contrast, an exclusive focus on individual subjects may inadvertently foster artificial compartmentalisation. This notion of a well-rounded education assumes relevance, especially in light of the contemporary challenges faced by our ever-evolving, increasingly global society, which invariably demands multidisciplinary solutions. Many of these challenges necessitate the integration of diverse STEM concepts for effective resolution (Wang et al., 2011), often blurring the boundaries between STEM disciplines, including Biology and Chemistry. In a world where internet access is readily available, the shift from rote memorisation of information to problem-solving is becoming progressively prominent (Cho, 2021). This transition is consistent with the perspective put forth by Hirst (1974), who argued that segregating subject areas obstructs learning by isolating students from real-world experiences—a viewpoint that resonates with more contemporary researchers advocating for problem-solving approaches within the integrated STEM paradigm to cultivate innovative thinkers endowed with interdisciplinary competencies (Brown, 2012; Corlu et al., 2014; Madden et al., 2013).

Similarly to Cumiskey (2022), it is worth emphasising that the pursuit of cross-curricular integration does not aim to dissolve individual subjects but seeks to create a more meaningful and interconnected educational experience for students. In contrast, Wang et al. (2011), in their quantitative study investigating teachers' perceptions of STEM integration, discovered that one teacher's experience indicated that STEM integration could potentially enhance students' interest in learning mathematics. However, it did not necessarily lead to more effective subject-specific instruction. Ralston (2011) concurs with the notion that interdisciplinary education can free students from a state of disinterest, enabling them to recognise meaningful connections between their studies across different academic disciplines. More recently, Handtke and Bögeholz (2023) surveyed 271 biology, chemistry, and physics teachers in 2019, 2020, and 2021. Their findings underscored several prominent advantages of cross-curricular integration, including addressing essential 21st-century topics by interlinking content from these three subjects and fostering increased student interest. However, Handtke and Bögeholz (2023) also highlighted numerous challenges, notably the substantial time and investment required. This time-related challenge aligns with prior research, such as that conducted by Johnston et al. (2014), which indicated that time and timing played significant roles when implementing an integrated approach to teaching and learning in the domains of science and mathematics with the incorporation of technology. These findings parallel Cumiskey's (2022) observations that teachers often express concerns regarding the considerable time and effort needed to design and deliver integrated units, particularly in the context of existing curriculum demands, as evident in primary school settings. Taylor et al. (2019) raise the possibility of educational (feelings of competence and commitment) and logistical (lack of resources, funding, teachers' lack of preparation time) issues stemming from the diversity of "educational" characteristics found in secondary schools when compared to primary education. Connolly (2023) conducted research indicating that a primary challenge for teachers embarking on interdisciplinary learning initiatives was the time required for planning and designing combined lessons. Nonetheless, Connolly's findings suggest that this substantial challenge is not insurmountable, as teachers are generally willing to expand their collaborative experiences with colleagues. In contrast, Handtke and Bögeholz (2023) also noted that teachers may be motivated by factors such as their affinity for and education in a specific subject. Still, teachers might fear that adopting a cross-curricular context could compromise the depth of content coverage in their classes. This apprehension echoes the findings of Barnes (2015), who discovered that cross-curricular methods could be counterproductive when employed by primary school teachers with limited subject knowledge.

2.5 Exploring the Positive Impacts and Potential of Cross-Curricular Learning

Despite the prevailing challenges associated with cross-curricular learning, it is important to acknowledge its potential positive impacts on student motivation and confidence. Early (2019) conducted research in a primary school context and discovered that students often exhibited elevated belief and confidence when encountering a new lesson within a cross-curricular approach. This boost in confidence stemmed from their prior exposure to the thematic content on multiple occasions. At the post-primary level, Connolly (2020) observed that adopting a cross-curricular approach to teaching topics effectively engaged students, leading to a heightened sense of ownership and pride in their learning experiences. This suggests that cross-curricular strategies can foster a more profound understanding of connection and commitment to the educational process among secondary students. Moreover, White and Delaney (2021) conducted a comprehensive systematic review focusing on incorporating interdisciplinary learning, specifically within STEM contexts, in high school settings. Their review revealed a recurring theme: the implementation of curricular changes that encouraged interdisciplinary learning correlated with higher academic achievement and contributed to increased motivation for learning, enhanced problem-solving skills, and the development of a capacity for complex understanding among students.

As part of this review, 17 defined areas in which CCL can exist between the current Leaving Certificate Biology and Chemistry Syllabi displayed in Appendix 1 (Department of Education and Skills, 2001; Department of Education and Skills, 2013). This data was gathered to clearly define the potential for CCL and learning opportunities available at Leaving Certificate level. Only one piece of research was available which discussed any of the links covered in Appendix 1. You et al., 2021 investigated the concept of Carbon Cycling and its interdisciplinary nature, spanning various science disciplines, including biology, chemistry, earth science, and physics. In this study, ten experts were interviewed. The findings of You et al.'s research indicated a noteworthy shift in the recommended approach from disciplinary-based instruction to an interdisciplinary mode when teaching the Carbon Cycle. Additionally, the study advocated for providing professional development opportunities to enhance multidisciplinary teaching practices. Such professional development initiatives would assist educators in effectively guiding students in organising their disciplinary knowledge, facilitating the establishment of meaningful interdisciplinary connections, and ultimately fostering the development of desirable scientific literacy among students.

As previously delineated, cross-curricular learning offers numerous advantages and holds potential for existing and future implementation across various educational domains. Prospective avenues for research in this field encompass the reconceptualisation of disciplinary boundaries and the refinement of professional identities among educators (Ralston, 2011). This process may entail the alignment of curricula with other STEM disciplines within their respective subject domains (Wang et al., 2011). Additionally, it is imperative to underscore the importance of continuous professional development initiatives tailored to interdisciplinary teaching practices, as You et al. (2021) highlighted. These initiatives, such as those offered by the Professional Development Service for Teachers (PDST) in various STEM subject areas (Department of Education and Skills, 2020), are instrumental in equipping educators with the necessary tools to facilitate the organisation of disciplinary knowledge among students.

While the prospect of incorporating Chemistry and Biology across the curriculum holds promise, as Wang et al. (2011) suggested, this research project confines its focus to the application of cross-curricular learning specifically within the context of Leaving Certificate Biology and Chemistry. It is worth noting that while the exploration of suitable guidelines for the implementation of cross-curricular learning is still in its nascent stages (White and Delaney, 2021), this study endeavours to investigate current teacher perceptions and practices pertaining to cross-curricular learning in the context of Leaving Certificate Biology and Chemistry. The study aims to address the following research questions:

- How do teachers define cross-circular links between Leaving Certificate Biology and Chemistry?
- What are teachers' beliefs and perceptions regarding integrating academic achievement when Chemistry and Biology at the Leaving Certificate level?
- What is the relationship between teachers' beliefs and perceptions regarding biology and chemistry integration and the practical reality of delivering this in the classroom?

In conclusion, exploring CCL within the context of Ireland's Leaving Certificate Biology and Chemistry curricula reveals significant potential for enhancing educational outcomes. By bridging traditional subject boundaries, CCL can foster a more interconnected and meaningful learning experience, which aligns with global trends and addresses the increasing demand for STEM competencies. Despite the evident challenges, such as the time investment required and the necessity for professional development, the advantages of CCL—including increased student motivation, engagement, and interdisciplinary understanding—underscore its value. As Ireland advances in STEM education, learning from international practices and integrating innovative approaches like CCL will be crucial.

Having established the importance and implications of CCL, the next chapter will delve into the methodologies employed in this study to investigate current teacher perceptions and practices regarding CCL in Leaving Certificate Biology and Chemistry. This will include a detailed examination of the research design, data collection techniques, and analytical strategies used to address the research questions, thus providing a comprehensive framework for understanding the practical realities and potential of CCL in Irish secondary education.

Chapter Three

Methodologies

3.1 Introduction

This chapter contains the methodological considerations adopted for designing, implementing and evaluating CCL and their academic achievement. This text explains a conceptual framework. The study is divided into various defined stages. The sample is described, and ethical concerns related to it are highlighted. The research instruments used in the study are also described. Validity and reliability issues are considered, and the analysis methods are indicated. This chapter aims to delineate the methods employed in the study. It facilitates replicability, crucial for scientific scrutiny, by offering a transparent account of research design, data collection, and analysis. The transparency of this study enhances the credibility of findings, allowing others to verify and build upon the research. Ethical considerations, such as participant consent and privacy safeguards, are discussed. The chapter discusses the specifics of data collection methods, whether surveys, experiments, interviews, or observations are suitable and corresponding data analysis techniques. We will also discuss the limitations, which will add nuance to the interpretation of the research. By addressing validity, reliability, and contextualising the study within the broader field, the methodologies chapter serves as a comprehensive guide, enabling readers to assess the study's robustness and relevance within the academic landscape (Tong et al., 2012).

3.2 Research Design and Consideration

3.2.1 Choosing a research paradigm

Research paradigms are frameworks that guide scientific discoveries through their underlying assumptions and principles. In order to understand the quality of findings that support scientific studies and identify gaps in generating sound evidence, it is important to have a clear understanding of the specific assumptions of each paradigm. Different paradigms have been studied through various research methodologies. Positivism, for instance, relies on the hypothetico-deductive method to verify a priori hypotheses, which are usually stated quantitatively. This method allows for the identification of functional relationships between causal and explanatory factors (independent variables) and outcomes (dependent variables) (Ponterotto, 2005). Interpretivism emerged as a critique of positivism, focusing on subjective perspectives. Instead of examining surface-level variables, interpretivism seeks to understand the deeper contextual factors. It recognises that humans are distinct from physical phenomena, as they create layers of meaning that cannot be explored similarly. Interpretivism highlights the need to consider individuals' unique perspectives and experiences when studying social phenomena (Alharahsheh and Pius, 2020).

In recent years, there has been an increase in what has become known as mixed methods research, which has been highlighted through the publication of mixed methods research books (Teddlie and Tashakkori, 2010; Creswell and Plano Clark, 2017) and the publication of articles concerned with mixed methods research and its application in the Journal of Mixed Methods Research. Researchers adopting a pragmatist stance will opt for methods that 'work best' for their project, and such projects are often associated with a mixed-methods methodology. A pragmatist project rejects conventional notions of objectivity and subjectivity, effectively allowing the research to use two different approaches.

3.2.2 Research Methods

Much has been written about quantitative and qualitative research approaches and their differences (Guba, 1990; Bryman, 2008a; Gray, 2021). While quantitative and mixed methods research results in much success for researchers, this thesis will utilise qualitative methods to profoundly explore complex phenomena and understand the context in which they occur. A qualitative methodology, emanating from interpretivism, involves collecting data that the researcher will interpret in some way. Anthropologists and sociologists developed qualitative research, often naturalistic, ethnographic, or subjective (Denzin and Lincoln, 2011). Qualitative research is particularly adept at capturing rich, detailed data, such as narratives and participant perspectives, providing a nuanced understanding (Tracy, 2019). The flexibility allows the research to be adapted to an approach which includes emerging insights, making it suitable for dynamic research questions. Qualitative methods excel at generating hypotheses, informing subsequent quantitative research, and contributing to theory-building by exploring new concepts and relationships (Grodal et al., 2021). The emphasis on in-depth interviews facilitates examining personal experiences and attitudes (Karlsson et al., 2018).

A study conducted by Ho (2022) investigated how teachers use qualitative data in their decision-making processes, challenging the predominant emphasis on quantitative data. The paper discussed using systematically and unsystematically collected qualitative data, including informal sources like conversations and observations. The results of this paper found that qualitative data informs teachers' professional judgment and instructional decisions, highlighting the need to recognise and appropriately incorporate qualitative data in education despite concerns about its impact on rational decision-making processes. Researcher papers with similar findings (Jamal, 2013; Horgan et al., 2023) aided in the decision-making process for this research. Qualitative purists, such as constructivists and interpretivists, contend that reality emanates solely from the subjective knower (Johnson and Onwuegbuzie, 2004). The data gathered is characterised as "rich in the description of people, places, and conversations, and not easily managed by statistical procedures" (Bogdan and Biklen, 1997). In addition, qualitative research accommodates smaller sample sizes, which makes it worthwhile when obtaining large samples is challenging.

3.3 Research Strategy

Practitioners in education have developed action research, management organisational change and social theory (Larkin, 2004). The researcher was drawn to using a semi-structured interview as the research strategy as they were working as a student Biology and Chemistry teacher when research began and welcomed the opportunity to work with a group of experienced teachers in a "reflective" and "participatory manner" (Carr and Kemmis, 1986). Face-to-face semi-structured interviews were selected as part of this research based on research conducted into this interview style, which aligned with the researcher's views (Irvine et al., 2013; Bearman, 2019; Brinkmann, 2014). As a qualitative research method, a semi-structured interview integrates a predetermined set of open questions that encourage discussion with the flexibility for the interviewer to delve deeper into specific themes or responses. As suggested by Kallio et al. (2016), researchers should consider proceeding systematically using a five-step process to develop a semi-structured interview guide and justify its decisions. This approach was adopted during the developmental process.

3.4 Research Instruments

A meticulous and ethically sound approach is imperative in identifying and recruiting research participants from the science department within a rural mixed-sex school with over 700 students. This necessitates a comprehensive delineation of the criteria prospective participants must satisfy to qualify for inclusion in the study. Within this academic institution, a characterised tenure involves proactive engagement and relationship-building, particularly with the science faculty, establishing a foundation for the forthcoming recruitment endeavour. Before approaching potential participants, due diligence was exercised to secure explicit permission and support from pertinent authorities within the academic hierarchy. This procedural step aligns with ethical considerations, ensuring institutional guidelines and protocols are followed. The ensuing engagement with participants will involve a transparent and informative communication strategy, wherein all pertinent details of the study will be conveyed lucidly and succinctly.

Furthermore, a commitment to upholding participants' rights and responsibilities will underscore each interaction. This ethical commitment extends to disseminating information through established school communication channels, specifically emphasising utilising platforms such as the science faculty Microsoft Teams channel to reach and engage potential participants effectively. This approach is designed to foster an environment of transparency, trust, and ethical responsibility throughout the research recruitment process within the academic setting.

During this investigation, the researcher adopted an interpretive paradigm. The chosen research methodology will be qualitative, employing a sampling technique of five face-to-face, short, semi-structured interviews. The selection of participants for these interviews will adhere to a purposeful sampling approach, a non-probability technique wherein individuals are chosen based on specific characteristics pertinent to the research inquiries and objectives delineated earlier. This method facilitates the deliberate selection of participants capable of offering comprehensive and detailed insights related to the study. Within the rural mixed-sex school with over 700 students, criterion sampling will be employed, wherein participants are selected based on explicit criteria relevant to the research questions. This approach aims to identify individuals within the selected academic institutions who fulfil the criteria and are actively employed therein. By concentrating on this specific cohort, the study aims to garner insights from individuals whose characteristics align with the research focus, thereby enhancing the information's relevance and depth.

3.5 Data analysis

The results of the semi-structured interviews will be analysed using thematic analysis. Thematic analysis is a crucial and intricate approach within the realm of qualitative analysis (Holloway and Todres, 2003). It is an essential tool that researchers should learn first, providing fundamental skills that can be applied in other qualitative analysis forms. In fact, "thematising meanings" has been identified as one of the few shared generic skills across qualitative analysis, making it a cornerstone of the field. Although some scholars consider it a tool to be utilised in different methods, Boyatzis (1998) argues that thematic analysis should be recognised as a research interpretation method. Thematic analysis is a poorly demarcated and rarely acknowledged yet widely used qualitative analytic method (Boyatzis, 1998; Roulston, 2001).

Braun and Clarke (2019) found many insights into thematic analysis, including the fact that it is noteworthy that diverse approaches to thematic analysis exist, and they may not necessarily align with one another seamlessly. Acquiring awareness of this diversity and adopting a deliberate, informed approach to thematic analysis can clarify conceptualisations and practical applications. Braun and Clarke also suggested that researchers select a thematic analysis approach that aligns with the purpose of their research and resonates with their analytical sensibilities, including theoretical and conceptual frameworks. To emphasise the importance of quality in thematic analysis, researchers should develop a nuanced understanding of their methodologies, the rationale behind their choices, and the criteria that define successful execution (Vaismoradi, Turunen, and Bondas, 2013). This foundational comprehension is pivotal for the proficient implementation of reflexive thematic analysis. The thematic analysis for this research will be based on the implementation and evaluation of CCL and their academic achievement.

3.6 Rigour

In qualitative research endeavours, scrutinising a project's trustworthiness hinges significantly upon establishing credibility—a metric denoting the believability and reliability of study findings (McDonald et al., 2019). Several pivotal strategies contribute to ensuring the credibility of the research process (Hatch, 2023). First and foremost, triangulation, entailing the utilisation of diverse data sources or methodologies, validates findings through the corroboration of information from varied channels (Flick, 2004). Incorporating member checking, a practice involving presenting research outcomes to participants for validation or correction (Motulsky, 2021), provides an additional layer of scrutiny by integrating the perspectives of those directly involved. Furthermore, engaging in peer debriefing, wherein external colleagues examine the research process and outcomes (Spall, 1998), enables the introduction of alternative viewpoints and the identification of potential biases. The meticulous maintenance of audit trails and documentation, encompassing methodological decisions and procedural changes, ensures transparency and facilitates external evaluation. Lastly, reflexivity, denoting the researcher's ongoing self-awareness regarding their positionality and biases, contributes to the overall credibility of the study by elucidating the context within which the research unfolds (Braun and Clarke, 2019). Collectively, these measures establish a robust framework for enhancing the credibility of qualitative research endeavours.

3.7 Limitations

In delineating the parameters of this diminutive-scale inquiry, it is imperative to conscientiously acknowledge the inherent limitations attendant to such an investigatory scope. Primarily, the issue of generalisability and transferability is underscored by the constrained sample size intrinsic to investigations of modest scale (Finfgeld-Connett, 2010), rendering the discerned patterns and outcomes circumscribed to the specific demographic and milieu under examination. The reliance on a singular methodological approach further accentuates potential shortcomings, notably the absence of triangulation, which, by design, encompasses diverse methods to fortify the integrity of empirical findings. Bias looms large in small-scale endeavours within the qualitative domain, given the propensity for subjective interpretation coupled with the limited participant cohort. It is indispensable to candidly elucidate the ramifications of these constraints, encompassing the potential circumscription of perspectives and interpretive subjectivity.

Furthermore, an exhaustive consideration of resource constraints, temporal constraints, and unanticipated difficulties engenders an in-depth understanding of the circumscribed reliability of the study's outcomes. In proactively disclosing these limitations, this research augments scholarly transparency, facilitating nuanced interpretation and establishing a foundational framework for prospective investigations. Concurrently, delineating avenues for future research underscores the evolving nature of scholarly discourse and imparts a conscientious trajectory for subsequent inquiries seeking to redress these acknowledged limitations.

3.8 Ethics

The research will adhere to the guidelines established by the British Educational Research Association (BERA); all research endeavours must uphold a rigorous ethical framework. As stipulated by BERA (2018), researchers are required to embrace an "ethic of respect" (p. 5), underscoring the imperative for conscientious consideration of ethical responsibilities throughout the research process (Zwozdiak-Myers, 2020). A foundational ethical obligation entails securing explicit consent from participants before initiating any aspect of the research, coupled with a commitment to ensuring that the research activities do not expose participants to any potential risks or harm. The data collection phase demands a reasonable and responsible approach, characterised by sensitivity and affirmation, with meticulous attention devoted to the wording of questions, the use of person-first language, and thoughtful consideration of the researcher's response to any signs of participant distress or discomfort.

Integral to the ethical conduct of research is a commitment to fostering participant understanding. Accordingly, participants engaged in educational research must be equipped with a comprehensive understanding of the significance of their role, with explicit consent being sought for their involvement in the study or intervention. Clear and transparent communication of procedures is paramount, necessitating the provision of information to participants regarding the Hibernia College opt-in procedure. This entails furnishing participants with detailed research information through a Research Information Sheet and a Consent Form Letter. To safeguard the integrity of the research process, we mandate rigorous measures to ensure the confidentiality of all submitted data and results. This excludes identifying individual participants, including pupils/students or teachers and institutions such as schools or colleges.

In terms of data management, electronic copies of data are to be securely stored in an encrypted folder/directory, protected by password access on the researcher's laptop or computer. Hard copies of data must be stored in a secure filing system. A stipulated three-year retention period following data collection, by Hibernia College's privacy policy, is to be observed. Subsequently, all data must be systematically and securely deleted, aligning with the provisions of the General Data Protection Regulation (GDPR).

This chapter provides a detailed overview of the methodological framework used to create, implement, and assess CCL and how it affects academic achievement. We describe the research design, ethical considerations, research instruments, data collection methods, and analysis techniques to ensure transparency and rigour. This detailed explanation ensures that other researchers can replicate and validate our study. We also discuss the limitations, providing a nuanced interpretation of our findings while acknowledging the constraints of our approach. In the next chapter, we will analyse the data collected from semi-structured interviews to gain a deeper understanding of the perspectives and experiences of the participants, which will enhance our knowledge of CCL's implementation and its impact on academic achievement.

Chapter Four

Findings

4.1 Introduction

The findings chapter of this thesis provides an in-depth exploration of the integration of Chemistry and Biology within the Leaving Certificate curriculum. The chapter focuses on the perspectives and experiences of five experienced educators and sheds light on interdisciplinary teaching. Through qualitative interviews, it illuminates various aspects of CCL between these two scientific disciplines. The chapter explores the effects and limitations of implementing interdisciplinary teaching strategies in the classroom and strategies for addressing adversities associated with CCL. It emphasises the importance of thoughtful planning and ongoing support to achieve academic success.

Five teachers with significant experience in their subject areas, ranging from five to over twenty years, were interviewed as part of the research. While the interviewees needed to have experience in either Biology or Chemistry, there were teachers with expertise in other subjects, including Agricultural Sciences and Mathematics. These interviews showcase the versatility of the educational landscape and highlight the diverse range of teaching experiences that students can encounter. Furthermore, they underscore the variety of specialisations and expertise that teachers can bring to the classroom.

4.2 Understanding and Defining of CCL

Throughout the interviews, each participant offered their unique perspective on CCL Chemistry and Biology at the Leaving Certificate level. The participants had varying levels of understanding of the concept. Some recognised the connections between the two subjects, such as the relationship between the Periodic Table and biological processes like digestion, photosynthesis, and respiration. Some acknowledged the interdependence between the subjects, adapting their teaching approach to the student's prior knowledge of chemistry. One interviewee suggested that integrating the two subjects is a valuable tool that enhances our understanding of phenomena. It explains how chemical principles influence biological processes and breaks down boundaries between disciplines. The benefits of exploring Chemistry and Biology together to promote interdisciplinary thinking and improve comprehension abilities were also discussed. However, some teachers lacked experience in highlighting the connections between the subjects, and some suggested that integration should be optional, as it may not benefit all students in the class for their future studies or careers. No correlation was found between teacher who taught more than one subject and their knowledge of CCL. They argued that subject content should be taught without emphasising CCL. These interviews uncovered diverse approaches to integrating Chemistry and Biology, ranging from selective incorporation to comprehensive interdisciplinary understanding reflecting educators' pedagogical philosophies and priorities.

4.3 Awareness of Cross-Curricular Connections

Several responses were received regarding the awareness of the overlap between the Biology and Chemistry syllabi. While most interviewees recognised and appreciated the cross-curricular connections, others were unaware of the substantial overlap between the two subjects. However, the importance of incorporating discussions around these overlaps was emphasised. Some interviewees knew of the links but felt that more substantial connections could be made to facilitate learning for students enrolled in both subjects. On the other hand, some teachers clearly understood the overlap and mentioned biochemistry and environmental science as areas where Biology and Chemistry converge. Although the commonalities were highlighted, some argued for prioritising each subject's curriculum as standalone entities to ensure the subject is not diluted. The responses revealed varying levels of awareness and focus on interdisciplinary connections within Biology and Chemistry, reflecting the diverse approaches and priorities within science education.

4.4 Perceptions of Impact on Academic Achievement at Leaving Certificate in Biology and Chemistry

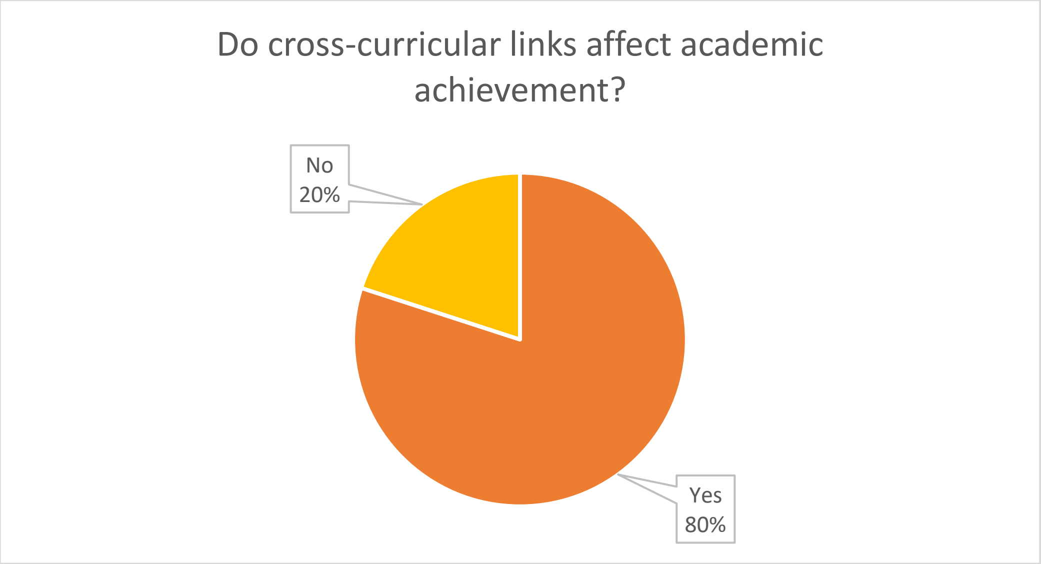

Figure 3. Do cross-curricular links affect academic achievement?

It is evident from Figure 1 that the majority of the interviewees recognised a link between academic achievement and CCL. Some teachers mentioned that reinforcing students' understanding by revisiting outcomes related to both subjects can benefit students in various ways within the classroom. For instance, collaborative planning among teachers can enhance academic achievement in interconnected topics, such as the nitrogen or carbon cycle. Maximising these benefits could be achieved by raising students' awareness of them. One teacher suggested that highlighting these connections can improve knowledge retention. It is believed that linking Biology and Chemistry can give students a sense of relief and an advantage when they recognise familiar topics across different subjects. Moreover, linking these subjects can help students better grasp scientific understanding by emphasising their connections and promoting critical thinking. Some interviewees suggested that understanding how these subjects are related can help students tackle complex concepts and increase their critical thinking. Numeracy was also noted to enhance students' analytical skills for future endeavours.

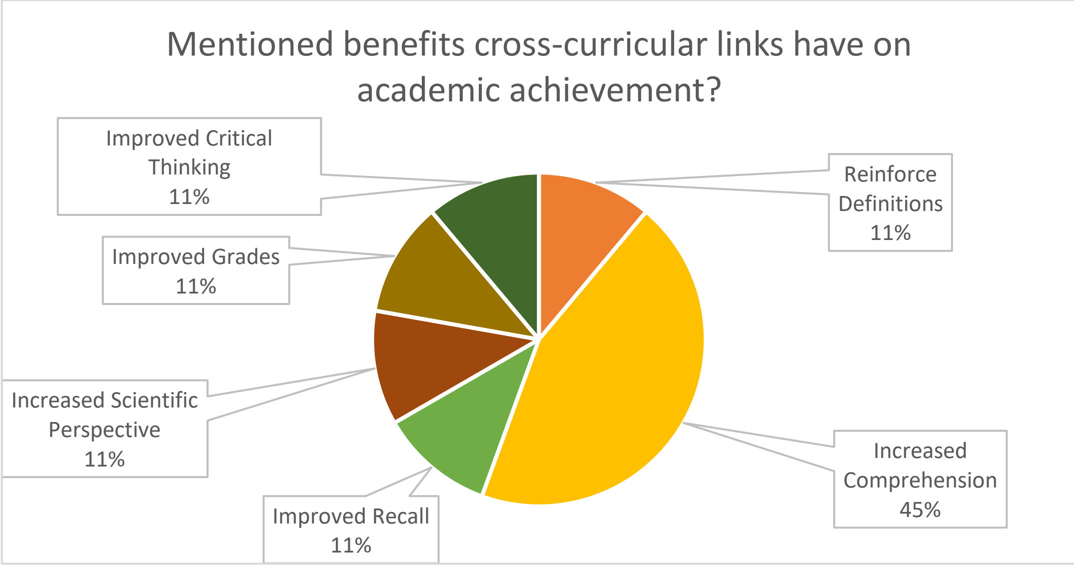

Figure 4. Mentioned the benefits cross-curricular links have on academic achievement.

The frequency and diversity of benefits mentioned are illustrated in Figure 2. While improved grades were cited as a benefit of learning both subjects for the Leaving Certificate, some interviewees expressed that integrating Biology and Chemistry in a Leaving Certificate may not significantly impact students' grades. This may be because everyone has different interests and career goals, and incorporating both subjects may not benefit all students.

During the discussion on academic performance, certain limitations were considered, particularly concerning the cross-curricular connections between Biology and Chemistry. It was noted that some students who only take one of the two sciences may become confused. Therefore, it was suggested that the marking schemes be closely evaluated to assess their impact on student responses. It was also emphasised that understanding the student's background is essential and that care should be taken not to overload students with unrelated chemistry content, as this may lead to a decreased understanding of a particular topic. The time constraints and the challenge of covering multiple subjects within a time-poor curriculum were identified as additional challenges. One participant noted that while there may be no limitations on students' grades, there is a potential loss of focus on subject specifics if interconnectedness is relied on. The mixed results on academic limitations of the interconnectedness of Biology and Chemistry reflect the complex nature of integrating two senior cycle subjects. Various responses addressed adversities that may stem from emphasising CCL between Biology and Chemistry. The feedback highlighted several approaches and factors necessary to tackle the educational obstacles. These include the adoption of innovative curricula and personalised teaching methods that factor in students' backgrounds and experiences. This approach ensures students receive content tailored to their unique abilities and potential challenges. Participants also suggested prioritising core concepts and establishing connections between subjects to mitigate adverse outcomes. Additionally, offering professional development opportunities to teachers to access interdisciplinary resources and enhance integration efforts can boost student engagement and success. Establishing a solid foundation in fundamental subjects, such as maths, is essential before introducing multidisciplinary learning. The responses emphasise the significance of strategic planning, targeted support, and continuous professional development to address these challenges effectively.

4.5 Opportunities, Experiences and Strategies with Integrated Teaching

Educators have different experiences regarding integrated teaching, ranging from a lack of opportunity due to educational contexts to voluntary integration. Some teachers who voluntarily integrated Biology and Chemistry noted that it was not discussed during subject-planning meetings, pointing to potential challenges with institutional support for interdisciplinary subjects. However, one teacher reported a positive experience teaching Chemistry and Biology, highlighting the enriching discussions and connections between the two subjects. This teacher believes that interdisciplinary teaching has potential benefits for students and educators and found the experience rewarding. Another teacher spoke about the opportunities to integrate mathematics and numeracy to enhance comprehension of mathematical concepts within a scientific context. These responses demonstrate the varied opportunities and experiences around integrating Biology and Chemistry during the Senior Cycle. Important areas to consider include institutional support, teacher initiative, and the potential benefits of interdisciplinary approaches in fostering holistic learning experiences. During the senior cycle, teachers can carefully consider how they can effectively integrate Biology and Chemistry into their teaching approach in accordance with the school's philosophical beliefs. Only two of the teachers shared their practices when implementing CCL. They stressed the significance of acknowledging diverse learning styles and abilities and recommended hands-on experiments and group projects to bridge the gap between Biology and Chemistry. These insights demonstrate the interviewees' dedication to fostering interdisciplinary thinking and a well-rounded educational experience. Moreover, another teacher who provided their input also values interdisciplinary learning and proposes utilising mathematical problems in lab experiments and data analysis to increase its effectiveness. These findings showcase the flexibility and ingenuity that can be utilised to facilitate the integration of Biology and Chemistry. Although only two teachers shared their experiences, it is essential to recognise that these strategies were believed to enrich student's learning experiences and promote cross-disciplinary comprehension.

4.6 Observed Effects of Implementing Cross-curricular Links in Post-Primary

Valuable insights were gained from the feedback on implementing CCL across any relevant subject in the post-primary classroom. The interviews revealed that integrating different subjects can have potential benefits, such as aiding students' understanding of complex topics and increasing their confidence. Participants specifically noted the interconnectedness of Biology with Home Economics and Agricultural Science and how prior knowledge can assist comprehension. The practical element of subjects was also highlighted, which can aid hands-on and non-traditional learners. One interviewee shared an example of how students' prior knowledge of a topic from a previous class helped them understand a more complicated concept, showcasing the benefits of subject integration. Overall, the interviews demonstrated that linking different subjects encourages student engagement and enhances understanding by demonstrating real-life applications of scientific concepts. Participants also noted that the interconnectedness of diverse scientific ideas enhances critical thinking and problem-solving skills. However, not all interviewees valued CCL, with one participant expressing scepticism and preferring to teach core content separately. The responses concerning CCL reflect the diversity in pedagogical approaches and highlight various believed advantages, such as promoting comprehension, critical thinking, and problem-solving skills.

4.7 Resources and Supports for Integration

Based on the survey responses, collaborative planning, professional development opportunities, and access to interdisciplinary teaching materials are essential for seamlessly integrating Biology and Chemistry. To foster collaboration among teachers, one interviewee recommended that subject planning and meetings be held to identify areas for integration and develop integrated resources, such as a nitrogen cycle map that emphasises biological and chemical aspects. The survey participants proposed regular meetings during working hours or continuous professional development (CPD) sessions to encourage collaboration and innovation. Furthermore, it was suggested that schools, government bodies, and science groups be connected to create engaging learning opportunities across various subjects. The survey also highlighted the importance of guidelines or training opportunities to explicitly access materials that support the Leaving Certificate curriculum and aid integration. Ultimately, the survey results emphasise the need for comprehensive support to integrate Biology and Chemistry successfully.

Overall, from all five interviews conducted, the interconnectedness of Biology and Chemistry in the Leaving Certificate is an area that is not strongly established throughout the curriculum. These results underscore the complexity of integrating Biology and Chemistry into the Leaving Certificate curriculum and highlight the importance of teacher perspectives, institutional support, and strategic planning to address challenges and maximise benefits. While some have adapted it, CCL has reoccurring benefits for most interviewees. Implementing such CCL comes with difficulties when, if focused on in the future, it should be supported using suitable resources. This chapter thoroughly examines how Chemistry and Biology are integrated in the Leaving Certificate curriculum, based on qualitative interviews with experienced educators. The findings reveal diverse perspectives on interdisciplinary teaching, varying awareness regarding connections between subjects, and different perceptions of the impact on academic achievement. The benefits and challenges of implementing cross-curricular learning (CCL) were highlighted, emphasising the need for careful planning, strategic support, and continuous professional development. These insights highlight the complexity and potential of interdisciplinary approaches in education, emphasising the need for tailored strategies to improve learning outcomes. The next chapter will provide a detailed discussion of these findings, exploring their implications and placing them in a broader educational context. This analysis will offer a deeper understanding of how cross-curricular links can be effectively integrated to promote academic success and holistic educational experiences.

Chapter Five

Discussion

5.1 Introduction

This chapter critically examines the integration of Cross-Curricular Learning (CCL) within the Irish education system, specifically focusing on the intersection of Chemistry and Biology in the Leaving Certificate curriculum. This chapter underscores the imperative of adopting innovative educational strategies to sustain and enhance Ireland's standing in STEM education by contextualising global trends in STEM education and comparing Ireland's position to other nations. Drawing on insights from the literature review and addressing key research questions—namely, how teachers define cross-curricular links between Leaving Certificate Biology and Chemistry, their beliefs and perceptions regarding the integration of these subjects and its impact on academic achievement, and the relationship between these beliefs and the practical realities of classroom delivery—the chapter provides a comprehensive overview of the structural features of the Irish education system and their implications for CCL.

The evolution and definition of CCL are explored, highlighting its potential to bridge disciplinary gaps and augment STEM learning. The chapter further scrutinises the impact of CCL on academic achievement and student engagement, supported by empirical studies and interview data. Challenges associated with implementing CCL, such as curricular constraints and teacher preparedness, are discussed alongside opportunities for professional development and institutional support. This comprehensive analysis aims to elucidate the current state and future potential of CCL in the Irish education system and provide a foundation for further discourse and development in this area.

5.2 The Irish Education System and CCL

The global emphasis on science and other STEM-related literacies has been previously highlighted (Cooper and Berry, 2020). Ireland's positive uptake of Senior Cycle science subjects, compared to the US, UK, and Australia, is evident (Archer et al., 2013; Means et al., 2017; Commonwealth Australia, 2017). While this is a favourable position, the Irish education system should look to learn from other countries' efforts in continually advancing STEM education. By adopting such strategies, including CCL, Ireland can solidify its position as a leading STEM country. The research findings align with the perspectives identified in the literature review and contribute to a comprehensive understanding of the current situation. It is important to note that the literature review encompassed both secondary and primary education, resulting in a robust dataset. Another critical consideration is that the data collected during interviews may be limited due to the lack of official recognition of the CCL in the Irish education system.

In the Irish education system, subjects in the Leaving Certificate post-primary curriculum are distinctly separated, possibly reflecting the Teaching Council’s rigorous subject-specific standards. These standards are essential for maintaining the quality of newly qualified teachers, especially in specialised fields like the sciences (Department of Education and Skills, 2020). This structured approach, coupled with no official CCL recognition in Leaving Certificate subjects, may have resulted in varying levels of awareness of CCL among teachers. Connolly, Carr, and Knox (2023) argue that a curriculum should not simply consist of discrete subjects. The NCCA is moving towards a belief system similar to that of Connolly, Carr, and Knox in developing key skills for the Leaving Certificate in ‘Key Skills Initiative: Phase Three. Stories from the learning site’. So far, there is no indication from the SEC or the Teaching Council of any emphasis on linking topics within subjects such as Biology and Chemistry. These reasons may give rise to the lack of opportunity some interviewees mentioned when considering the implementation or awareness of CCL.

5.3 The Evolution and Definition of CCL

Arthur Bentley's analogy of linking interdisciplinarity methods with the various methods as tools within a figurative "laboratory" (Ratner et al., 1965) helps to clarify the relationships among different fields, such as Biology and Chemistry, especially in the context of individuals utilising laboratory skills. These relationships are further elaborated upon in this chapter. The literature review and interviews shed light on cross-curricular learning and its potential applications in STEM education. According to Barnes (2015), an interdisciplinary approach aims to connect or blend subjects creatively. This definition aligns with the connections between Biology and Chemistry mentioned in interviews, such as the relationship between the Periodic Table and biological processes like digestion, photosynthesis, and respiration. This illustrates the potential for cross-curricular learning to enhance the understanding and application of STEM subjects.

Ralston (2011) noted the purpose of interdisciplinarity is to "connect academic fields, subfields, or schools of thought". Ralston also mentioned that the process of CCL is difficult, but the goal is clear, which is reflected in the interviewees' experiences when discussing resources or support. Several interviewees suggested that subject planning and regular meetings should be held to identify areas for integration and develop integrated resources. This aligns with Ralston's idea that although defining explicit goals may be challenging, allocating time and resources to this area could help set boundaries and specific goals to achieve cross-curricular learning. During the interview, one participant highlighted the value of integrating two subjects to enhance our understanding of phenomena, explain the influence of chemical principles on biological processes, and bridge the gap between different disciplines. This perspective aligns with John Dewey's belief that education should not isolate scientific inquiry from the realm of literature but instead promote a mutually enriching process (Dewey, 1916). Cumiskey (2022) further emphasises that acquiring skills across different subjects in the curriculum supports Dewey's educational theories, enabling students to learn both in the classroom and throughout their lives. However, some interviewees expressed concerns about the integration of subjects, suggesting that teachers may lack experience in highlighting the connections between them. Some proposed that integration should be optional, as it may not benefit all students in their future studies or careers. Although not explicitly mentioned in current literature, this viewpoint aligns with

Weber's belief that specialising within a specific domain and contributing original insights aligns with loftier spiritual principles.

5.4 Impact of CCL

When considering the impact of CCL, it is essential to note the lack of empirical data for post-primary education in the literature review. White and Delaney (2021) pointed out a significant gap in the secondary education sector when examining interdisciplinary learning in schools, especially compared to primary and tertiary education. They highlighted the absence of empirically supported guidelines for educators who aim to integrate STEM disciplines such as Biology and Chemistry into their teaching practices alongside existing pedagogical approaches. While the interview results generally aligned with existing literature, it is worth noting that no quantitative data was presented to support the interview responses. It became apparent during questioning that most interviewees did perceive connections between academic achievement and CCL.

In their study, White and Delaney (2021) found that interdisciplinary learning is strongly connected to higher academic achievement, increased motivation for learning, improved problem-solving skills, and the development of a capacity for complex understanding among students. Interviews with teachers indicated that academic achievement, enhanced problem-solving skills, and the development of a capacity for complex understanding were all positively influenced by interdisciplinary learning. One teacher emphasised a direct correlation between CCL and academic achievement, using the example of the carbon or nitrogen cycles to illustrate positive academic outcomes. Another teacher mentioned that reinforcing learning through CCL aids written comprehension within the subject and gives students the confidence to understand complex topics. This finding is supported by Early's (2019) research, which revealed that students often demonstrated an elevated sense of belief and confidence when they encountered a new lesson within a cross-curricular approach. This was reflected in interviews when a teacher noted that students experience a sense of relief when they realise they have already learned a topic in another subject, giving them an advantage in understanding the topic. The study by Cho (2021) underscores the significance of problem-solving skills in the Internet age. The link between problem-solving and CCL emerged as a recurring theme in the interviews. Participants consistently stressed enhancing problem-solving abilities, comprehension, and students' capacity for complex understanding. One teacher emphasised that CCL not only aids in grasping scientific concepts but also nurtures vital skills such as critical thinking, problem-solving, and collaboration.

Moreover, this teacher believed integrating mathematical problem-solving into science subjects improved students' grasp of scientific principles and cultivated critical thinking, problem-solving, and analytical skills. The incorporation of mathematic principles into Biology and Chemistry was highlighted as a means for students to gain a deeper understanding of scientific concepts and to learn to approach complex problems from multiple perspectives. This aligns with Wang et al.'s (2011) belief that addressing many modern challenges necessitates combining knowledge from various STEM fields, often resulting in overlapping disciplines such as Biology and Chemistry. One teacher pointed out that combining Biology with Home Economics and Agricultural Science enables students to apply their knowledge of food science, photosynthesis, plant growth, and animal physiology across different subjects. This approach reinforces learning through connections between different disciplines and improves written comprehension within the subject, ultimately giving students the confidence to understand complex topics. Ralston's previously mentioned 2011 study found a significant impact of cross-curricular learning on deep comprehension, especially in Biology and Chemistry, as demonstrated by students' ability to address questions related to both subjects. Contrastingly to this, one interview teacher noticed that students who do not have this cross-curricular advantage may struggle with basic concepts. They observed that their students became "interested and excited when they see how science applies to real-life situations" when encountering cross-curricular learning. This directly relates to Handtke and Bögeholz's (2023) biology, chemistry, and physics survey, which found that cross-curricular learning would help students " address essential 21st-century topics by interlinking content from these three subjects and fostering increased student interest." Additionally, two interviewees emphasised the value of hands-on experiments and group projects despite these aspects not being explicitly mentioned in the existing literature.

5.5 Challenges and Concerns in Implementing Cross-Curricular Learning

The validity of the beliefs above is under scrutiny in academic literature. Cumiskey (2022) states that integrating subjects may obscure their distinctions, potentially reducing subjects to a singular, all-encompassing entity. One teacher expressed concerns about potential confusion among students if Biology questions incorporate excessive Chemistry and vice versa. They highlighted that this blurring of subjects could have a negative impact on students who intentionally opted out of studying Chemistry in favour of focusing solely on the biological aspect of the curriculum. The teacher also emphasised the comprehensiveness of the biology syllabus and suggested that emphasising the connection between Biology and Chemistry should only be pursued if it enhances students' understanding of biological concepts. Another interviewee proposed that integrating Chemistry and Biology does not significantly affect students' grades, as each student has interests and career aspirations and that not all students would benefit from this integration. Another teacher echoed this sentiment, stating that while they have not observed any adverse effects on students' grades, utilising integrated subjects might make it more challenging for students to concentrate on the specifics of each subject. As discussed, in the Irish education system, subjects in the post-primary curriculum remain distinct, which may explain the difficulties encountered by the interviewed teachers in implementing integrated subjects.

Two interviews raised a concern about prioritising teaching the core content in each subject before implementing cross-curricular learning. One interviewee acknowledged that connecting different subjects might be beneficial, but they had not observed any measurable advantages in their classroom. Therefore, they said they "focus on teaching the core content of each subject separately". Similarly, another teacher mentioned that while they value CCL, connecting each subject "might make it harder to focus on each subject's specifics". These viewpoints align with findings in the literature, such as Handtke and Bögeholz (2023), who noted that teachers' attachment to and expertise in a specific subject might lead them to worry that adopting a cross-curricular approach could compromise the depth of content coverage in their classes.

Handtke and Bögeholz (2023) emphasised challenges relating to the required time and effort when implementing CCL. In interviews, teachers also mentioned various challenges, including losing subject focus, time constraints due to a packed curriculum, and students' decreased understanding. One teacher highlighted the challenge of finding time for subject department meetings, stating that it is crucial but often difficult due to teaching schedules. They suggested regular meeting times or professional development to address these challenges. These findings align with Cumiskey's (2022) observations that teachers are concerned about the time and effort needed to create and deliver integrated units within existing curriculum demands. Another interviewee echoed this concern: "The biggest problem is that we don't have enough time to cover everything in the curriculum." Regarding students' decreased understanding, a teacher stressed the importance of considering students' backgrounds and not overwhelming them with unrelated content. Another interviewee agreed, emphasising the importance of students' prior knowledge when teaching cross-curricular learning. A third interviewee noted that teaching CCL to a class with few students taking both subjects will likely confuse other students. It is important to note that teachers accustomed to traditional teaching methods may resist change and feel unprepared to embrace the integrated STEM approach (El-Deghaidy et al., 2017; Hasni et al., 2015; Wells, 2011). This is an important consideration when evaluating the opinions of interviewees regarding the challenges of CCL.

5.6 Fostering Interdisciplinary Learning: Opportunities and Challenges in the Irish Education System

Recent research, such as Cumiskey (2022), emphasises that cross-curricular integration aims to enhance the educational experience for students by fostering a more interconnected and meaningful learning environment rather than replacing individual subjects. Cross-curricular learning (CCL) equips students with a more comprehensive education, enabling them to approach challenges from various perspectives. This approach is precious in addressing contemporary global issues, which demand interdisciplinary solutions. According to interviewees, interdisciplinary thinking promotes a holistic approach to science education. The NCCA seeks to prioritise skill development over knowledge acquisition, integrating essential skills into teaching individual senior cycle subjects (NCCA, 2010) and potentially encouraging cross-curricular connections. The increased emphasis on CCL by the NCCA in Senior Cycle may lead to greater recognition of CCL within specific Leaving Certificate subjects. Recognising CCL's value in other aspects of Irish education is also essential. The Transition Year and Leaving Certificate Applied programmes are designed to adopt an interdisciplinary and cross-curricular approach rather than a subject-based framework (DES, 1994; Irish Primary Principals Network, 2017). The values placed on CCL in these aspects of Irish education may influence the direction in which Senior Cycle may move.

Teachers pointed out another opportunity in interviews and research for CPD. Some teachers who voluntarily integrated Biology and Chemistry noted that this was not discussed during subject-planning meetings, and they also faced issues with institutional support for interdisciplinary subjects. Effective use of CPD could address these issues by covering topics suggested during interviews, such as adopting innovative curricula and personalised teaching methods that consider students' backgrounds and experiences. This would ensure that students receive tailored content matching their unique abilities. The findings clearly state the need for these resources and their instructional use. One teacher suggested using CPD to avoid missed student learning opportunities, such as implementing CCL. Another emphasised the importance of teacher professional development opportunities and collaborative initiatives among departments. A third teacher highlighted the need to provide teachers with ample professional development opportunities and access to resources spanning multiple fields to integrate Chemistry and Biology into the Leaving Certificate curriculum.

In this chapter, we thoroughly examined the integration of Cross-Curricular Learning (CCL) within the Irish educational framework, specifically focusing on how Chemistry and Biology intersect within the Leaving Certificate curriculum. We discussed global trends in STEM education, compared Ireland's approach to that of other nations, and emphasized the need for innovative teaching approaches to strengthen Ireland's position in STEM education. Our inquiry looked into how CCL is applied in post-primary classrooms in Ireland, highlighting its potential to bridge disciplinary gaps and enhance STEM learning paradigms, as well as its effects on academic achievement and student engagement. We also addressed challenges such as curriculum constraints, teacher readiness, and time constraints, and suggested avenues for professional development and institutional support. The findings in this chapter provide a strong foundation for understanding the current state and future potential of CCL integration in the Irish educational environment. The next chapter will offer a deeper synthesis and reflection on these findings, outlining their implications for future research and academic practice.

Chapter Six

Conclusion

This review underscores the potential of Cross-Curricular Learning (CCL) within the STEM educational framework, explicitly focusing on Leaving Certificate Biology and Chemistry in Ireland. The initial literature analysis covered research conducted between 2015 and 2023 in post-primary education. Still, broadening the scope to include prior years and primary education was necessary to gather relevant research papers. The analysis of this research revealed a growing interest in CCL to enrich educational experiences and meet the demands of the 21st century. Despite compartmentalising subjects within the post-primary curriculum at the Leaving Certificate level, there are positive trends towards STEM education in the literature. Evidence indicates a global decline in interest in senior science in countries such as the USA, UK, and Australia (Archer et al., 2013; Means et al., 2017; Commonwealth Australia, 2017). Given this trend, Ireland should continue to uphold and improve its STEM education standards, utilising methodologies such as CCL.

While the number of STEM graduates in Ireland is substantial, as reported by the Central Statistics Office (2019), this research emphasises the need to introduce CCL. The literature research and interview findings demonstrate that CCL can enhance students' comprehension and application of scientific concepts by bridging disciplines such as Biology and Chemistry. Those students studying only one science, particularly Biology, may not benefit from an increased focus on CCL. Differentiation of CCL and the curricula is always most vital when delivering syllabi.

The surveyed teachers recognised the potential benefits of CCL, including improved problem-solving skills, better comprehension, and increased student motivation, which aligns with the current literature (White and Delaney, 2021; Jacob, 1989). However, those interviewed also encounter challenges such as time constraints, lack of institutional support, and concerns about maintaining subject-specific rigour. These challenges may be attributed to the need for more official recognition of CCL in the Irish education system. Separating subjects in the Leaving Certificate post-primary curriculum may reflect the Teaching Council's stringent standards, which are essential for upholding the quality of preparation for newly qualified teachers, particularly in specialised fields such as the sciences (Department of Education and Skills, 2020).

Research indicates that cross-curricular learning positively influences academic achievement and student engagement. Educators have noted that students participating in interdisciplinary learning demonstrate increased confidence when tackling complex subjects. This observation is reinforced by Early's (2019) study, which revealed that students often display greater belief and confidence when encountering a new lesson within a cross-curricular framework. The research underscores the importance of providing teachers with professional development opportunities to implement CCL, emphasising the need for CPD effectively. The study also highlights a lack of CPD programs focused on interdisciplinary teaching methods and suggests that addressing this gap could lead to more widespread and effective CCL practices.

In the future, the NCCA could explore various opportunities to enhance the incorporation of CCL into senior cycle subjects, with a specific focus on science education. This initiative could involve creating comprehensive guidelines and developing tailored resources to support educators in effectively integrating the principles of CCL into subjects like Biology and Chemistry. By providing specific strategies and tools, the NCCA can empower teachers to cultivate these essential skills in students, ultimately enriching their learning experience and preparing them for future academic and professional endeavours. This recommendation would only work if other bodies, such as the State Examinations Commission and the Teaching Council, emphasised the importance of CCL and provided clear frameworks for its implementation. Each school community can contribute to encouraging CCL by allocating regular meeting times for subject departments to plan and develop integrated teaching resources. Collaborative initiatives among departments can enhance the effectiveness of CCL. Developing interdisciplinary teaching materials and resources that highlight connections between subjects, such as the Periodic Table and biological processes, should be prioritised.

When evaluating the influence of CCL on post-primary education, it is crucial to emphasise the need for comprehensive research to collect quantitative data on its impact, specifically at the post-primary level. It is essential to conduct longitudinal studies to understand the sustained benefits and potential challenges associated with interdisciplinary learning. This could involve tracking students' progress over an extended period to assess the lasting effects of CCL on their academic performance and overall educational experience. This study has some limitations that should be acknowledged. The main limitation is the need for more quantitative data to support some of the interview's qualitative findings. Additionally, focusing solely on the Irish education system may restrict the applicability of the findings to other contexts. Methodologically, the research faced challenges due to the absence of official recognition of CCL in Ireland, which may have influenced teachers' awareness and implementation of interdisciplinary approaches. However, despite these limitations, the study achieved its overall aims by providing a detailed analysis of CCL in Ireland and offering actionable recommendations for its improvement. Future research should continue to explore the empirical impacts of CCL and address the identified challenges to realise its full potential in enriching STEM education.

In conclusion, this chapter sheds light on the promising prospects of CCL within the STEM education landscape, explicitly focusing on Leaving Certificate Biology and Chemistry in Ireland. The comprehensive literature review spanning from 2015 to 2023, complemented by an exploration of earlier years and primary education, underscores a burgeoning interest in CCL to enhance educational quality and meet the evolving demands of the 21st century. While acknowledging the potential benefits of CCL, such as improved problem-solving skills and increased student motivation, educators face obstacles such as time constraints and lack of institutional support. Nonetheless, this research advocates for implementing CCL, emphasising the importance of professional development opportunities for educators and collaborative efforts among stakeholders to realise its full potential in enriching STEM education. Moving forward, comprehensive research efforts are needed to quantify the impact of CCL and address the identified limitations to ensure its effective integration into the educational landscape.

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Appendices

Appendix 1:Cross-curricular links between the current Leaving Certificate Biology and Chemistry Syllabi 2023.

Biology		Chemistry	
Topic	**In Syllabus**	**Topic**	**In Syllabus**
Scientific method Experimentation	1.1.2 and 1.1.3 (Department of Education and Skills, 2001, p.7) All practical activities (Department of Education and Skills, 2001)	The scientific method and proper experimentation processes are developed practical activities.	All practical activities throughout the syllabus. (Department of Education and Skills 2013)
Identification of the elements present in food, dissolved salts and trace elements	1.3.2 (Department of Education and Skills, 2001, p.9)	Elements. Symbols of the elements. (1-36)	1.1 (Department of Education and Skills 2013, p.7, p.37)
Test for starch.	1.3.4 (Department of Education and Skills, 2001, p. 9)	The use of starch as an indicator in mandatory activities	Mandatory activity 4.7 and Mandatory activity 4.8 (Department of Education and Skills 2013, p. 48) Mandatory activity 9.4 (Department of Education and Skills 2013, p. 64)
The use of Fehling's solution to test for the presence of reducing sugars.	1.3.4 (Department of Education and Skills, 2001, p. 9)	The use of Fehling's to distinguish between aldehydes and ketones.	Mandatory activity 7.4 (Department of Education and Skills 2013, p. 21, p.58)

Using NaOH and $CuSO_4$ solutions to test for protein	1.3.4 (Department of Education and Skills, 2001, p. 9)	NaOH appears widely in the syllabus. Using $CuSO_4$ solutions to illustrate electrolysis.	Mandatory activity 4.3 (Department of Education and Skills 2013, p. 48) 1.5 and Mandatory Activity 1.2 (Department of Education and Skills 2013, p. 9, p.40, p.41)
Fats and oils (lipids)	1.3.4 (Department of Education and Skills, 2001, p. 9)	Fats and oils are examples of esters.	7.2 and 7.3 (Department of Education and Skills 2013, p.19, p. 20, p.54, p.55, p. 56)
Digestion of fats to yield fatty (carboxylic acids) and glycerol.	3.3.4 (Department of Education and Skills, 2001, p. 34)	Hydrolysis of esters to yield carboxylic acids(fatty acids) and alcohol. Saponification of lard-producing sodium stearate (soap) and glycerol.	7.3 (Department of Education and Skills 2013, p. 20, p.56) Mandatory activity 7.2 Department of Education and Skills 2013, p.21, p. 58)
Vitamins are polar and non-polar and their solubility.	1.3.7 (Department of Education and Skills, 2001, p. 10)	Solubility in polar and non-polar solvents. Solubility of alkanes, alkenes, alkynes, alcohols, etc in water and organic solvents.	2.2 and 2.3 (Department of Education and Skills 2013, p. 10, p.42) 5.2 and 5.3(Department of Education and Skills 2013, p. 15, p. 49) 7.1 and 7.2 (Department of Education and

			Skills 2013, p. 19, p.54, p. 20)
The nitrogen cycle	1.4.8 (Department of Education and Skills, 2001, p. 11)	Natural fixation of nitrogen. The nitrogen cycle	1B.2 (Department of Education and Skills 2013, p. 29)
The carbon cycle	1.4.8 (Department of Education and Skills, 2001, p. 11)	The carbon cycle	1B.3 (Department of Education and Skills 2013, p. 29)
Pollution. Study the effect of any one pollutant.	1.4.9 (Department of Education and Skills, 2001, p. 11)	CO2 and its effect on global warming. The effects of CFCs on the ozone layer. Acid rain and its effect on the environment.	1.B3 (Department of Education and Skills 2013, p. 29) 1.B4 and 1.B5 (Department of Education and Skills 2013, p. 30)
Abiotic factor in a habitat e.g. pH. Use of pH paper or pH meter. Effect of pH on enzyme activity.	1.5.4 (Department of Education and Skills, 2001, p. 13) 2.2.3 (Department of Education and Skills, 2001, p. 8)	Use of universal indicator paper to measure pH of solutions. Use of a pH meter to measure the pH of water.	9.1 (Department of Education and Skills 2013, p. 25, p.2) 9.4 (Department of Education and Skills 2013, p. 26, p.64)
Definition of enzymes.	2.2.3 (Department of Education and Skills, 2001, p. 8)	Definition of catalyst.	6.2 (Department of Education and Skills 2013, p. 18, p.53)
The active site theory to explain enzyme function and specificity.	2.2.7 (Department of Education and Skills, 2001, p. 19)	Intermediate formation theory of catalyst.	6.2 (Department of Education and Skills 2013, p. 18, p.53)
Representation of photosynthesis by a	2.2.4 (Department of	Chemical equations. Balancing chemical	3.5 (Department of Education and

balanced equation. Respiration – representation by a balanced equation of the overall sequence of reactions for glucose.	Education and Skills, 2001, p. 8) 2.2.5 (Department of Education and Skills, 2001, p. 9)	equations. Balancing redox equations.	Skills 2013, p. 13, p.46)
The terms electrons and protons are used extensively in the study of photosynthesis and respiration.	2.2.4 (Department of Education and Skills, 2001, p. 8)	Atomic structure. The students are required to know the properties of electrons and protons.	1.2 (Department of Education and Skills 2013, p. 7, p.37)
Investigate the influence of CO2 on the rate of photosynthesis.	2.2.4 (Department of Education and Skills, 2001, p. 8)	Option 1B studies CO2 in detail.	1B.3 (Department of Education and Skills 2013, p. 29)

Appendix 2: Interview Questions

1. How many years of experience do you have in teaching Leaving Certificate Biology and Chemistry?

2. How do you personally define and understand the concept of integrating Chemistry and Biology at the Leaving Certificate level?

3. Were you aware of the extensive overlap (as outlined in Appendix 1) between the biology and chemistry syllabi, with more than 15 occasions where the two subjects intersect?

4. What are your perceptions regarding the impact of cross-curricular links between Leaving Certificate Biology and Chemistry on students' academic achievement?

5. At senior cycle, have you ever had the opportunity to teach an integrated Chemistry and Biology curriculum, and if so, what was your experience?

6. If yes to question 5, can you share any specific strategies or methods you use to integrate Biology and Chemistry, and how well do they align with your initial beliefs?

7. Based on current literature, cross-curricular links and subject integration can enhance comprehension, critical thinking, and problem-solving skills. Have you observed any positive effects of implementing cross-curricular links in your classroom?

8. In your teaching experience, have you noticed any limitations or adverse effects on students' academic performance when emphasising cross-curricular links between Biology and Chemistry?

9. If yes to question 8, how might the adversities be addressed?

10. What are your beliefs regarding the potential benefits or advantages of integrating Chemistry and Biology in the Leaving Certificate curriculum?

11. What resources or support do you believe would enhance the ability to integrate Chemistry and Biology effectively in the Leaving Certificate curriculum?

Appendix 3: Research Information Sheet and Consent Form

<table>
<tr><td>Researcher:</td><td></td></tr>
<tr><td>Organisation:
(name and contact details)</td><td>Hibernia College Dublin</td></tr>
<tr><td>Title of study:</td><td>Do cross-circular links improve academic achievement? A study of the advantages and limitations of implementing cross-circular links within the Leaving Certificate subjects Biology and Chemistry.</td></tr>
<tr><td colspan="2">Outline of research study:

In recent decades, there has been an increase in science, technology, engineering and mathematics (STEM) job vacancies, resulting in educational interest in post-primary education in Ireland. According to the Central Statistics Office (2019), Ireland had the highest number of Science, Technology, Engineering, and Mathematics (STEM) graduates in the EU27 in 2018, with a rate of 35.2 per 1,000 individuals aged 20-29. In developing positive attitudes towards STEM, school communities play a significant role, particularly for young adolescents. Teachers have the opportunity to connect what students learn in class with their future career paths. Still, it is essential to establish a strong foundation by developing cross-circular links between various STEM subjects.
In the past, experts such as Hadow (1931) and Plowden (1967) acknowledged that real-life challenges require the integration of various disciplines and skills. Throughout my SEPP1 placement, I gained a profound appreciation for the value of integrating different fields of study. Collaborating with my tutor, we prioritised incorporating at least one cross-disciplinary link in each lesson plan as we delved into the intricacies of Biology and Chemistry.
Teachers are faced with the challenge of incorporating interdisciplinary learning into STEM education due to its practical nature and diverse curricular components, as noted by White and Delaney (2021). As such, this study explores the advantages and limitations of implementing cross-circular links within the Leaving Certificate subjects Biology and Chemistry.

Objectives of the project:

The aim of this research project is to investigate the potential impact of incorporating cross-circular links between the subjects of Biology and Chemistry on academic achievement. By integrating concepts and principles from one subject into another, the researchers seek to determine whether students' understanding, performance, and</td></tr>
</table>

overall achievement can be improved. The project also aims to identify the advantages and limitations of implementing cross-circular links within these subjects. This includes investigating potential benefits such as improved comprehension, critical thinking, and problem-solving skills, and any challenges or drawbacks that may arise from integrating the two disciplines.

What would I need you to do?

Your participation in this research project is greatly appreciated. This research project has received ethical approval from Hibernia College Dublin. If you agree to participate, you will participate in a short semi-structured interview with the researcher. Any information you provide about your identity, or the school will be anonymous and confidential. Quotes from the interview may be used and may also be published in the research; however, your name and the name of the school will not be published. The interview will be audio recorded and transcribed; a copy of the transcript will be made available to you upon request. This research will be used in the publication of a thesis for Hibernia College Dublin. It may also be used in conference proceedings or in academic articles. You are free to withdraw from the study up to one month before the interview.

What is the purpose of this research?

The purpose of the research is to complete a small-scale study which forms part of the final year of the
Professional Master of Education (Primary) with Hibernia College Dublin.

Appendix 4: Research Information Sheet and Consent Form

Researcher:	
Organisation: **(name and contact details)**	Hibernia College Dublin
Title of study:	Do cross-circular links improve academic achievement? A study of the advantages and limitations of implementing cross-circular links within the Leaving Certificate subjects Biology and Chemistry.

Consent (to be completed by the participant)

Have you been fully informed/read the information sheet about this study? Yes/No

Have you had an opportunity to ask questions and discuss this study? Yes/No

Have you received satisfactory answers to all your questions? Yes/No

Do you understand that you are free to withdraw from this study up to one month before the interview without giving a reason for withdrawing and without your withdrawal having an adverse effect on you? Yes/No

Do you agree to take part in this study, the results of which are likely to be published or presented at a conference? Yes/No

Have you been informed that a copy of this consent form will be kept by the researcher? Yes/No

Are you satisfied that any information you give to the researcher will be kept confidential? Your name and the name of the school will not appear in the research report. Yes/No

Researchers name printed:

____

Signature:

____

Date: ____
Researchers name printed: ____ Signature: ____ Date: ____

Appendix 5: Principal Letter

Date: ________________

Dear __________________________

As part of my Professional Master's in (Primary/Post-Primary) Education with Hibernia College, I am conducting a study to investigate the advantages and limitations of implementing cross-circular links within the Leaving Certificate subjects Biology and Chemistry. Classroom teachers are key stakeholders in identifying these cross-curricular links to enhance student learning that can lead to further engagement in the classroom. This letter aims to provide you with an introduction to the research project and seek consent from you for the project to move forward to inform my future professional practice as a teacher.

With your permission, I would like to interview three classroom teachers. The staff will be asked to partake in semi-structured interviews to gain insight into the project's aims. Please find enclosed for your perusal, a copy of the information and consent forms. Only those respondents who return a signed copy of the consent form will be purposely selected to participate in the study. Any data gathering will strictly be underpinned by the school's ethical code of conduct. No students will be interviewed. Information gathered will be held in the strictest of confidence and pseudonyms will be used to ensure anonymity. The school's name will not appear on any research findings.

Interviews will be recorded, and the data will be securely held under Hibernia College Research Ethics guidelines. Participation in the study is voluntary; participants can withdraw from the research up to one month before the interview. The results from this research study will be reported in my research project and may be disseminated through professional publications.

I would appreciate your cooperation in providing access to the staff at the school over the coming weeks. If you have any queries or require further information on the research study, please do not hesitate to contact me.

Researcher: _______________________
Mobile: __________________________
Email: ___________________________

This research study has received Ethics approval from Hibernia College Dublin. If you have any concerns about this study and wish to contact someone independent, you may contact the School of Education, Hibernia College Dublin.

Researchers name:

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Date:

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Principals name:

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Date:

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Appendix 6: Transcription of Interview (Interview One) and identified areas of interest.

Teacher #1

1. How many years of experience do you have in teaching Leaving Certificate Biology and Chemistry?

I have been teaching Biology and Agricultural Science for just under five years. However, I do not have any experience teaching Chemistry.

2. How do you personally define and understand the concept of integrating Chemistry and Biology at the Leaving Certificate level?

I think there are some areas in biology that overlap with chemistry (awareness). For instance, we can study the Periodic table and the elements involved in processes like food digestion, photosynthesis, and respiration (example). However, I don't have much experience (limitation) in integrating chemistry and biology beyond these topics.

3. Were you aware of the extensive overlap (as outlined in Appendix 1) between the biology and chemistry syllabi, with more than 15 occasions where the two subjects intersect?

I personally didn't notice any overlap (awareness), except for the two sections that had a bit in common. Knowing that there are 15 more sections with common parts is interesting and it reminds me that I should talk more about chemistry (awareness). I usually emphasise the importance of cross-curricular learning between Biology and Home Economics and Agricultural Science (awareness), but now I'll consider chemistry a bit more.

4. What are your perceptions regarding the impact of cross-curricular links between Leaving Certificate Biology and Chemistry on students' academic achievement?

I think it would be beneficial for students to reinforce or rebuild certain definitions by revisiting similar learning outcomes (benefit) in both chemistry and biology. This way, they can remember the concepts better (benefit). I believe there should be more cross-curricular links between the two subjects, and students should be made more aware (future/opportunity) of them.

5. At senior cycle, have you ever had the opportunity to teach an integrated Chemistry and Biology curriculum, and if so, what was your experience?

Personally, I have not no(opportunity).

6. If yes to question 5, can you share any specific strategies or methods you use to integrate Biology and Chemistry, and how well do they align with your initial beliefs?

N/A

7. Based on current literature, cross-curricular links and subject integration can enhance comprehension, critical thinking, and problem-solving skills. Have you observed any positive effects of implementing cross-curricular links in your classroom?

When I am asked about cross-curricular learning, I tend to think of Biology in combination with Home Economics and Agricultural Science. Our Home Economics department has a wealth of knowledge about food science (opportunity/ awareness), and students who take this class tend to have prior knowledge (benefit) about certain topics that we can link to Biology. Similarly, agricultural science covers topics such as photosynthesis, plant growth, and animal physiology (awareness/opportunity), which can be linked to biology. I believe that reinforcing learning (benefit) through these links aids written comprehension (benefit) within the subject and gives students the confidence to understand complex topics (benefit). The connection between different practical subjects is also beneficial for hands-on learners and can benefit non-traditional learners as well (benefit).

8. In your teaching experience, have you noticed any limitations or adverse effects on students' academic performance when emphasising cross-curricular links between Biology and Chemistry?

I understand that the practical activities (opportunities) in school provide all the necessary resources. However, there might be confusion among students if Biology questions involve too much Chemistry and vice versa (limitation). This may negatively impact those who purposely did not select Chemistry and are focusing on the biological aspect of the curriculum. I have not yet reviewed the marking schemes where the two subjects overlap, but it would be interesting to see if different styles of answers are rewarded for these questions (limitation/ future), such as a more biological or chemical approach.

9. If yes to question 8, how might the adversities be addressed?

I believe the new syllabus (future) will hold a lot of these answers within in it and new issues will also arise from it, we have to wait and see I suppose.

10. What are your beliefs regarding the potential benefits or advantages of integrating Chemistry and Biology in the Leaving Certificate curriculum?

The benefits of learning chemistry are immense. Students who are taught chemistry gain a thorough understanding of biomolecules in biology (benefit). They have a deep comprehension of concepts (benefit), as evident from their ability to answer questions (benefit) about the elements found in certain biomolecules. However, those students who lack this cross-curricular advantage may find themselves struggling with basic concepts (limitation), such as identifying elements on the periodic table, despite having studied it in the Junior Cycle.

11. What resources or support do you believe would enhance the ability to integrate Chemistry and Biology effectively in the Leaving Certificate curriculum?

I understand that planning subjects beforehand can be very beneficial (resources/ opportunity/ future). Once the academic year has started, making significant changes becomes difficult (limitation). Subject planning can encourage teachers to collaborate with each other and identify areas where they can work together (opportunity). As a Biology and Agricultural Science teacher, I understand the relation between these two subjects, but I may not think of linking Chemistry. I usually connect Home Economics with the food section of Biology and the essential elements we need to consume (opportunity), but I think it would be better to highlight where these elements are on the periodic table and why they are there (example/ opportunity). Although I consider Biology and Chemistry as distinct sciences, I believe that it's time for us to start sharing notes during subject planning sessions (future/ resources/ opportunity). We could even create a map of the nitrogen cycle that highlights the biological and chemical aspects for students who are studying both subjects (example/ opportunity).