

**Investigating the Effectiveness and Teachers' Perceptions
of Rigorous Curriculum Design for Project-Based
Learning Implementation on Middle School Science
Students' Achievement and MAP scores in a Private
School in Abu Dhabi, UAE**

دراسة حول تصورات المعلمين وفعالية اعتماد المنهج الصارم للتعلم القائم على
المشاريع في تحصيل طلاب العلوم في المدارس المتوسطة ومعدلات قياس
تقدمهم الاكاديمي في احدى المدارس الخاصة في أبو ظبي ، الإمارات العربية
المتحدة.

by

NOURA FOUAD ASSAF

**A thesis submitted in partial fulfilment
of the requirements for the degree of
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ABSTRACT

Background and Purpose: Project-based learning (PBL) is an active student-centered instructional that has been explored in various contexts of schooling over the years. While the majority of the reviewed studies were conducted in North America, Europe, and part of Western Asia, very limited studies were conducted in the MENA region. Achieving proficiency in science requires students to learn through a high-quality curriculum that allows them to participate in authentic practices resembling scientists' work that enhance their skills, sustain motivation, and increase their achievements. Therefore, the Rigorous Curriculum Design (RCD) framework was adopted in this study to develop PBL curriculum units that align standards, instruction, and assessments. Since countries' educational systems accountability is currently evaluated based on student's achievements in external benchmark assessments and while students are still underperforming in benchmark assessments particularly Measure of Academic Progress (MAP) in the United Arab Emirates (UAE) this study aimed to Investigate the Effectiveness and Teachers' Perceptions of RCD for PBL Implementation on Middle School Science Students' Achievement and MAP scores in a Private School in Abu Dhabi, UAE.

Methods: Guided by the perspectives of Vygotsky's social constructivist theory and Dewey's experiential learning theory, an explanatory sequential mixed method design was used in this study. Science Standards Knowledge Test (SSKT), teachers' questionnaires, MAP results, and teachers' interview questions were adopted as tools for collecting data. Participants included N=304 middle school students, mostly Emiratis, middle school science teachers N=25, and six middle school science teachers that were purposively selected and interviewed as they implemented the RCD-PBL curriculum units. Descriptive and inferential statistics were used to analyze the results of the quantitative tools while thematic analysis was used for the qualitative data.

Results: The findings revealed several significant results: 1) implementing RCD-PBL has increased grades 6 to 8 students' Pre-Posttest results in the SSKT in the experimental group compared to the control group. 2) implementing RCD-PBL has increased the students' spring 2022 results in the MAP science exam for the experimental group compared to the control group for grades 6 to 8. 3) Teachers' perceptions have evolved whereby they are more confident about the implementation of the RCD-PBL. They indicated how their involvement, understanding of

the RCD-PBL, competencies, knowledge, and professional development were very important factors that influenced the curriculum design process and its successful implementation. In addition to the type of assessment (GRASPS), resources, delivery time, leadership, and parental involvement and support. Teachers have indicated that RCD-PBL curriculum units provided a coherent, cumulative, and well-sequenced enriched curriculum that helped improved and achieved the quality of education needed for their students and had a positive effect on improving their results in science benchmark exams.

Implications, contributions, and recommendations: It was evident that students were underperforming in benchmark exams due to the lack of a high-quality curriculum that enhances their skills and ensures their engagement in science. In addition, teachers are facing many challenges as they struggled to figure out the best ways to address the standards, plan, and implement PBL in UAE. The isolation that they faced as pioneers in implementing such an approach peripheral to the curriculum in K-12 education was also evident. Therefore, investigating the effectiveness of implementing PBL science curriculum units using the RCD while grasping teachers' perceptions towards their involvement in the development and implementation process could enhance all UAE students' results in benchmark exams and help all educational leaders in the country to reach the UAE National Agenda 2031 and 2071. Therefore, further research is suggested with regards to monitoring the effectiveness of RCD-PBL on MAP scores for more than one academic year, investigating the effectiveness of such curricula in different subjects, grade levels, and impact on genders, increasing parental involvement, and examining their perceptions towards such curriculum design.

Key Words: Project-Based Learning, Rigorous Curriculum Design, MAP exams, Teachers' perceptions, Students' achievements.

الخلاصة

خلفية البحث والغرض منه: ان التعلم القائم على المشاريع هو عملية تعليمية نشطة تركز على الطالب، وقد تم اكتشافها في سياقات مختلفة من التعليم على مر السنين. في حين أن غالبية الدراسات التي تمت مراجعتها قد أجريت في أمريكا الشمالية وأوروبا وجزء من غرب آسيا، يبقى عدد الدراسات في منطقة الشرق الأوسط وشمال أفريقيا محدود للغاية. يتطلب تحقيق الكفاءة في العلوم من الطلاب التعلم من خلال منهج دراسي عالي الجودة يسمح لهم بالمشاركة في ممارسات واقعية تشبه عمل العلماء، الامر الذي يعزز مهاراتهم ويحافظ على دوافعهم ويزيد من إنجازاتهم. لذلك، تم اعتماد إطار تصميم المناهج الصارمة في هذه الدراسة لتطوير وحدات المناهج الدراسية التي توفق بين المعايير والتعليم والتقييم. نظرا لأن مساءلة الأنظمة التعليمية في البلدان يتم تقييمها حاليا بناء على إنجازات الطلاب في التقييمات المرجعية الخارجية، وبينما لا يزال أداء الطلاب ضعيفا في التقييمات المرجعية وخاصة مقياس التقدم الأكاديمي (في دولة الإمارات العربية المتحدة، فقد هدفت هذه الدراسة إلى دراسة في فعالية وتصورات المعلمين ل RCD لتنفيذ PBL على تحصيل طلاب العلوم في المدارس المتوسطة ودرجات مقياس التقدم الأكاديمي في إحدى المدارس الخاصة في أبو ظبي، الامارات.

اساليب البحث: بارشاد من وجهات نظر نظرية فيجوتسكي البنائية الاجتماعية ونظرية ديوي للتعلم التجريبي، تم استخدام تصميم طريقة مختلطة متسلسلة تفسيرية في هذه الدراسة البحثية. تم اعتماد اختبار المعرفة لمعايير العلوم (SSKT)، واستبيانات المعلمين، ونتائج مقياس التقدم الأكاديمي، وأسئلة مقابلة المعلمين كأدوات لجمع البيانات. وكان من بين المشاركين 304 من طلاب المدارس المتوسطة، معظمهم من الإماراتيين، و25 مدرس علوم في المدارس المتوسطة، وستة معلمي علوم في المدارس المتوسطة تم اختيارهم ومقابلتهم أثناء تنفيذهم التعلم القائم على المشاريع لوحدات المناهج الدراسية. تم استخدام الإحصاءات الوصفية والاستدلالية لتحليل نتائج الأدوات الكمية بينما تم استخدام التحليل المواضيعي للبيانات النوعية.

النتائج: كشفت الخلاصات عن العديد من النتائج الهامة: (1) أدى تنفيذ التعلم القائم على المشاريع، و تصميم المناهج الصارمة إلى زيادة نتائج ما قبل الاختبار البعدي للطلاب من صفي السادس والثامن في اختبار المعرفة لمعايير العلوم في المجموعة التجريبية مقارنة بالمجموعة الضابطة. (2) أدى تنفيذ التعلم القائم على المشاريع، و تصميم المناهج الصارمة إلى زيادة نتائج الطلاب في فصل الربيع الدراسي للعام 2022 في امتحان العلوم على مقياس التقدم الأكاديمي للمجموعة التجريبية مقارنة بالمجموعة الضابطة للصفوف من 6 إلى 8. (3). وقد تطورت تصورات المعلمين بحيث أصبحوا أكثر ثقة بشأن تنفيذ التعلم القائم على المشاريع، و تصميم المناهج الصارمة وأشاروا إلى أن مشاركتهم في تنفيذ التعلم القائم على المشاريع، و تصميم المناهج الصارمة، وكفاءاتهم، ومعارفهم، وتطورهم المهني، كلها عوامل هامة جدا أثرت على عملية تصميم المناهج الدراسية وتنفيذها بنجاح. بالإضافة إلى اعتماد تقييم حقيقي قائم على الأداء، والموارد ووقت التسليم والقيادة ومشاركة الوالدين ودعمهما. وأشار المعلمون إلى أن وحدات المناهج الدراسية توفر منهجا دراسيا ثريا متماسكا وتراكميا ومتتابعيا بشكل جيد يساعد على تحسين وتحقيق نوعية التعليم اللازم لطلابهم وكان له أثر إيجابي على تحسين نتائجهم في امتحانات العلوم المعيارية.

الآثار والمساهمات والتوصيات: كان من الواضح أن أداء الطلاب كان ضعيفا في الامتحانات المعيارية بسبب عدم وجود منهج دراسي عالي الجودة يعزز مهاراتهم ويضمن مشاركتهم في العلوم. بالإضافة إلى ذلك، يواجه المعلمون العديد من التحديات

حيث يكافحون لمعرفة أفضل الطرق لمعالجة المعايير والتخطيط وتنفيذ التعلم القائم على المشاريع في الإمارات العربية المتحدة. كانت العزلة التي واجهوها كرواد في تنفيذ مثل هذا النهج المحيطي بالمناهج الدراسية في التعليم من رياض الأطفال إلى الصف 12 واضحة أيضا. لذلك، فإن التحقيق في فعالية تنفيذ وحدات مناهج العلوم في وتنفيذ التعلم القائم على المشاريع باستخدام تصميم المناهج الصارمة مع فهم تصورات المعلمين تجاه مشاركتهم في عملية التطوير والتنفيذ يمكن أن يعزز نتائج جميع طلاب دولة الإمارات العربية المتحدة في الامتحانات المعيارية ويساعد جميع القادة التربويين في الدولة على الوصول إلى الأجندة الوطنية لدولة الإمارات العربية المتحدة 2031 و 2071. ولذلك، يقترح إجراء مزيد من البحوث فيما يتعلق برصد فعالية تصميم المناهج الصارمة و التعلم القائم على المشاريع على درجات مقياس التقدم الأكاديمي لأكثر من عام دراسي واحد، والتحقيق في فعالية هذه المناهج الدراسية في مختلف المواد، ومستويات الصفوف، وتأثيرها على الجنسين، وزيادة مشاركة الوالدين، ودراسة تصوراتهم تجاه تصميم هذه المناهج.

الكلمات المفتاحية: التعلم القائم على المشاريع، تصميم المناهج الدراسية الصارمة، امتحانات مقياس التقدم الأكاديمي ، تصورات المعلمين، إنجازات الطلاب.

DEDICATION

This dissertation is dedicated to my parents who have taught me the value of education. Thank you for your constant and unwavering love, support, and encouragement. To my sister and brother who have accompanied me throughout the journey and helped me to relax and take a break whenever needed.

To Petra, this is for you. I hope that I have provided you with a role model of determination and commitment you can carry into your adulthood. Thank you for your patience on all the weekends and vacations spent at home, so that I may write. The sky is your limit, set your goals and dreams, and let nothing stops you from achieving them.

Lastly to my husband, partner, and friend, Elias. You have been my greatest critic and my biggest support. Without you, I would not know how to face this life with grace and courage. You have been my strength throughout it all. Thank you for believing in me and my capabilities.

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LIST OF ABBREVIATIONS

- PBL: Project-based learning
- RCD: Rigorous Curriculum Design
- MENA: Middle East and North Africa
- MAP: Measure of Academic Progress
- UAE: United Arab Emirates
- MOE: Ministry of Education
- NWEA: Northwest Evaluation Association
- RIT: Rasch Unit
- NGSS: Next Generation Science Standards
- ADEK: Abu Dhabi Department of Education and Knowledge's
- IB: International Baccalaureate
- PYP: Primary Years Programme
- MYP: Middle Years Programme
- DP: Diploma Programme
- AP: Advance Placement programme
- LPP: Legitimate Peripheral Participation
- CPD: Continual Professional Development
- PD: Professional Development
- GRASPS: Goal, Role, Audience, Situation, Product, and Standards
- STEM: Science, Technology, Engineering, and Mathematics
- KHDA: Dubai Knowledge and Human Development Authority
- PISA: Programme for International Student Assessment
- SPSS: Statistical Package for the Social Sciences
- ANOVA: Analysis of Variance
- LSD: Fisher's least squared difference
- HSD: Honestly Significant Difference
- ZPD: Zone of Proximal Development

- SEP: Science and Engineering Practices
- DCI: Disciplinary core ideas
- CC: Cross Cutting Concepts
- PE: Performance Expectation
- BIE: Buck Institute of Education
- IQWST: Investigating and Questioning our World through Science and Technology
- UbD: Understanding by Design
- CCSS: Common Core State Standards
- ICT: Information and Communications Technology
- GCC: Gulf Cooperation Council
- ASG: Achievement Status Growth projection report

CHAPTER I: INTRODUCTION

1.1 Overview of the Chapter

Project-based learning (PBL) has been developed, endorsed, and used to various degrees in schools for many years, especially in North America, Europe, and part of Western Asia. Currently, few schools in the Middle East and North Africa (MENA) regions are using the PBL approach for specific year group levels, subjects, or for off-curriculum time. While PBL seeks to: engage students more deeply with learning in areas that they have never thought about before, increase knowledge retention, improve academic achievements and allow them to be lifelong learners (IBO 2013; Condliffe et al., 2016; Sahli, 2017; Chen and Yong-Cih, 2019; Saavedra, Liu and Haderlein, 2021; Krajcik et al., 2021); limited studies on the implementation and evaluation of the effectiveness of PBL on students' achievements (Condliffe et al. 2016; Eckersall 2017; Sahli 2017; Rubrica 2018; Yokom 2020) have been carried out in the MENA region.

In addition, very few studies have investigated the effectiveness of this approach on students' achievements if advocated and developed as the basis of their whole curriculum, especially in middle school science classrooms. Therefore, developing a suitable and sustainable PBL science curriculum based on the Rigorous Curriculum Design (RCD) framework developed by Larry Ainsworth and designed by teachers should meet the context, culture, and work-driven needs of the second language learners and bridge the gap between what and how students are learning to how they are applying the knowledge and skills in real-world scenarios. Therefore, rethinking and redesigning our curriculum, instructions, and assessments in a way that upskills second language learners and withstands their motivation, and prepares them for international benchmark assessment (Schleicher 2020; United Nations 2020) is critical. While there is competition between countries in various fields, education is the most significant one (Nakhaee & Nasrabadi 2019). Education is considered the most powerful and important field that can influence any country's national vision (Retnawati, Hadi & Nugraha 2016) and helps prepare future leaders and successful citizens through developing individuals' competencies. In addition, it is a keystone to economic modernization as envisioned by the United Arab Emirates (UAE) first president Sheikh Zayed Bin Sultan Al Nahyan who emphasized the importance of

investing in his people as the success and prosperity of his nation are held and measured by its education standards (ADEC 2015; Kamal & Trines 2018). Hence, this study aims to investigate the effectiveness and teacher perceptions of RCD for PBL implementation on middle school science students' achievement and Measure of Academic Progress (MAP) scores in Abu Dhabi, UAE.

According to the United Arab Emirates Ministry of Education (MOE), preparing learners of all ages to meet the future workforce and market demands can only happen through the development of an innovative educational system and competitive global society (Ministry of Education 2019). Hence, to live in an interconnected, dynamic, and developed country like the UAE and take part in its upcoming knowledge-based economy requires members to acquire essential skills and build their abilities to become effective leaders and viable citizens (Ministry of Education 2019). Moving towards this knowledge-based economy is firmly connected to satisfying and acquiring the twenty-first-century demands and skills pivotal to changing the processes, structures, and practices of current schools in order to make teaching and learning more relevant (Goh & Dimmock 2011; Ponnusamy & Gopinathan 2013; Jamhari, Syarifuddin & Sipahutar 2018).

Although the UAE allocates a big part of its budget for education and highlights the ambition of the country to become among the top countries in the world in mathematics, reading, and science and be considered the main supplier of world-class education in its 2021 national agenda, nothing has been translated yet into visible outcomes (Kapsoli & Ruxandra Teodoru 2017). Following the 2021 national agenda, the UAE national agenda 2031 (UAE 2018) was released to support the objectives of the national agenda 2021 to generate effective solutions to current and upcoming challenges. Alternatively, the UAE cabinet launched a five-decade plan that concentrates on four main pillars that intend to make the UAE the best country in the world by 2071. This plan is known as UAE centennial 2071 whereby education occupies the second pillar to which the country gives a great deal of attention to. Acquiring the essential knowledge and skills for upcoming generations is the aim of the five-decade UAE centennial plans (UAE Centennial 2071 2022) for which “future-focused government” is the first pillar that focuses on spreading happiness in its society and establishing the best government in the world as a result of its inspirational leadership and long-term vision. The second pillar is related to education and is known as excellent education. This pillar highlights the importance of focusing on specific

areas (health science, engineering, innovation, advanced science and technology, and space science) and achieving an outstanding quality of education. In addition to other educational and institutional measures such as teaching students and encouraging education sectors to be both centers for international research and also incubators of entrepreneurship. A diversified knowledge economy that aims to make the UAE one of the top economies worldwide and the most competitive one is the third pillar of this centennial plan. The final and fourth pillar is a happy and cohesive society that focuses on the UAE community development through ensuring the happiness of its citizens and a positive lifestyle.

While H.H. Sheikh Mohammed Bin Rashid Al Maktoum has stated that several plans will be completed by 2021 as per the vision stated, the long-term centennial plan focuses more on the future generations and requires collaboration and cooperation of all individuals (UAE Centennial 2071 2022). A specific focus on education is dedicated to achieving the required changes and fulfilling the requirement indicated by Sheikh Mohammed in terms of equipping the upcoming generations with the necessary tools, knowledge, and skills that will enable them to succeed in the new world and be ready for the new types of jobs that will arise.

This chapter began with an overview of the research study. The remainder of this chapter presents the background and motivation of the study, the statement of the problem, the purpose and objectives of the research, the research questions, the justification of the study, the importance of the study and lastly a brief outline of each chapter in the thesis.

1.2 Background and Motivation of the Study

Ensuring quality education and promoting lifelong learning skills can only happen through the implementation of a proper pedagogical approach that is embedded in a well-established curriculum that bridges between education and the development of competencies (Philip 2016). While 36 curricula exist in the UAE, there is no overarching curriculum document across this country that connects goals, standards, and content (Ridge, Kippels & Farah 2017). Examination of the current curriculum in the UAE is heavily focused on textbooks whereby students rely heavily on memorizing concepts (teacher-centered approach) rather than constructing their knowledge through practices (student-centered approach) (Ridge, Kippels & Farah 2017). In addition, the government, school leaders, curriculum developers, teachers, and other stakeholders need to work collaboratively to positively impact students' achievements.

Looking over the diversity of subjects delivered in today's classrooms, the only subject that has a linear and direct relationship to building learners' cognitive and meta-cognitive skills while adopting a scientific approach to problem-solving is science (Hanauer & Bauerle 2012). While teachers play an essential role in creating a safe educational environment where students can exchange with comfort and confidence their thoughts and inventions, science teachers must use the appropriate pedagogical approach and strategy that motivate their students and increase their engagement through tasks that allow them to demonstrate their understanding and skills and allow them to be thinkers, problem solvers and reflective learners (Saido et al. 2015). Therefore, teachers need to be involved in and supportive of the implementation of a curriculum that centralizes around a pedagogical approach that will allow students to acquire a deeper knowledge through active exploration and real-world problems and challenges and ensure the transfer of students' knowledge and skills to a higher developmental level (Saido et al. 2015).

Therefore, to improve the quality of education and prepare the future generations for the new workforce, solve problems, and face the challenges, a suitable and sustainable curriculum model such as the Rigorous Curriculum Design by Larry Ainsworth that involves all members' participation and centralizes around students was used to develop Project-Based Learning science units that will equip the learners with the needed knowledge and skills and evaluate them through authentic project-based assessment and external examinations. While several prescriptive curriculum models have been evaluated and implemented over the course of the years such as those of Tyler, Taba, Saylor, Alexander, and Lewi, Oliva, and Wheeler; similar features are shared among them when designing and developing a curriculum (learners, society and subject under study) regardless of the approach adopted in every model whether inductive or deductive (Oliva 2005; Soto 2015). However, all these models highlighted that the driving force that shapes any curriculum and influences the choice of a model is the philosophy of education adopted in the schools or institutions where the curriculum is being reconstructed or designed (Oliva 2005; Tyler 2013).

Despite numerous attempts to design a high-quality curriculum that is coherent and connected, students still perceive science as a set of disconnected facts (Liu, Lee & Linn 2010) that need to be memorized (Sikorski & Hammer 2017). Referring to the K-12 Science Education framework (National Research Council 2012) and the Next Generation Science Standards (NGSS) (NGSS Lead States 2013) vision, students can achieve proficiency in science if they

are involved and engaged in authentic scientific practices and assessments. This vision can be realized if students learn from a high-quality curriculum (National Research Council 2012a). While most curriculum designers aim to establish an organized sequence that connects between standards, concepts, practices, and assessments and makes sense as a whole (Beane 1995), achieving cognitive coherence and engagement is still limited (Shwartz et al. 2008). Therefore, in order to make science learning experiences accessible to all predominantly non-native English speakers' (Simpson, Sunder & Gabler 2017), UAE private schools should not adopt readymade curricula from western countries but rather train and involve their teachers in designing standardized, concept-based curricula giving that the culture, learning experience, interests, and needs of students in eastern countries are different (Seaman & Nelsen 2011; Alshammari 2013; Tyler 2013). Looking through the Abu Dhabi Department of Education and Knowledge's (ADEK) evaluative objectives for private school sectors, ensuring a world-class education system that is either equivalent or superior to international standards is critical (ADEK 2020b, 2020a). This can only happen through adopting an appropriate pedagogical approach within a well-established curriculum design that offers depth in concepts as per international standards as well as flexible learning pathways and assessment styles (ADEC 2015).

Referring to ADEK's private school evaluative objectives and the school philosophy and strategic goals, the RCD model developed by Ainsworth (2011) served as a roadmap for the teachers to design and build units following the three fundamental stages described by Ainsworth: building foundation, designing and implementing curricular units (Ainsworth 2011; Ainsworth & Donovan 2019). This new approach to curriculum design is a practical pathway to a clear outcome, whereby the design covers all essential topics for students in a way that will be flexible, adaptable, and continuously changing depending on students' progress. This will, in turn, ensure a highly engaging classroom experience which caters to students' different learning needs and encourage those who may be shy or reluctant to participate. Furthermore, the model revolves around students adapting to practical experiences thus making learning accessible for everyone. Also, this model encompasses essential characteristics of PBL, which help to address specific college and career-ready standards (National Center For Education Statistics 2017; Bani-Hamad & Abdullah 2019).

In addition, the traditional educational system that promoted a readymade educational level was turning out to be a failure in comparison to the PBL approach. The knowledge

acquired through traditional pedagogical approaches are in no way comparable to the practical skills and well-rounded knowledge acquired through project-based learning. The level of students' engagement in PBL tasks was far greater than that of the assignments given to students in the readymade curriculum approach as explained by various teachers. These PBL tasks helped increase students' accountability and raised their motivational levels, thus allowing them to achieve more and perform better via practical learning. The knowledge acquired from PBL tasks was far better and in accordance with the real world in comparison to readymade textbook knowledge that is limited and theoretical by nature. The students who learned via a curriculum that involved the PBL approach were more intelligent than those who did not, and were better able to inquire, question, and make inferences to reach a solution when faced with any on-ground anomaly (Gökhan. 2011).

Given that teachers play a vital role in enhancing the quality of education, their involvement, subject knowledge, and capabilities will affect and impact the quality of any educational implementation (Mantra 2017). However, the gap between curriculum reform theory and implementation in the classroom continues to be a source of worry (Zhenyu 2012). As teachers' involvement and endorsement are required for the successful development and implementation of any curriculum (Keys & Bryan 2001; Tyler 2013), the RCD-PBL adopted and used in this study will not only ensure a solid ground for their involvement and collaboration but also address the learning gap and serve as a predictor of students' achievement (Ainsworth & Donovan 2019). The research studies by Keys & Bryan (2001); Hanauer & Bauerle (2012); Tyler (2013); Saido *et al.* (2015); Ridge, Kippels & Farah (2017); Simpson, Sunder & Gabler (2017), motivated me to carry out this research study, since very few studies have been done before, specifically for Abu Dhabi, UAE, that investigates the effectiveness and teachers' perceptions of Rigorous Curriculum Design for project-based learning implementation on middle school science students' achievement and MAP scores.

1.2.1 Context of the Study

This research study took place in one of the largest private schools with two campuses in the Emirates of Abu Dhabi. With more than 4000 students and 200 teachers, the school has five other sister campuses throughout the Emirates of Abu Dhabi, Dubai, Ras El Khaima, Al Ain, and Sharjah. The school learning pathway begins in preschool and continues its journey

through middle school and high school where it rests on the framework of the International Baccalaureate and the United State Common Core and Next Generation Science Standards Curriculum. In addition, high school students in grade 11 have a choice either to access the IB Diploma Programme or College Board Advanced Placement (AP) Programme. A diverse international staff and teachers body work in this reputable school in which students are mostly Emirati. Due to the school culture and values, students are separated by gender from grade 5. Whether new joiners or returning teachers, the school offers external and internal professional development in the IB programme whether Primary Years Programme (PYP), Middle Years Programme (MYP), or Diploma Programme (DP) as well as the AP programme to both.

As this study focuses on science, more specifically middle school science classrooms, all middle school science teachers across all Emirates were involved in a continuing professional development (CPD) on RCD, PBL, and NGSS from the academic year 2020-2021. Further support and training sessions were conducted every Tuesday in the allocated professional development time at the school in the academic year 2021-2022. PBL science curricula units were developed in collaboration with all science teachers across these campuses by using and following the RCD model for grades 6 to 8. As authentic and meaningful learning was at the core of the RCD, PBL, and NGSS, the performance-based assessment also known as project-based assessment such as GRASPS tasks were developed for each unit of inquiry. Such assessments were evaluated against a rubric out of 8 levels based on the MYP success criteria chosen whereby criterion A, assesses students' knowledge and understanding, criterion B assesses inquiring and designing, criterion C assesses processing and evaluating, and finally, criterion D assesses reflecting on the impact of science. Since PBL is a common method of teaching and learning in International Baccalaureate institutions and schools that focuses on students' deep comprehension of the concepts (Stock 2018; Tesla Eduvation 2021), the PBL assessments are by default the project around which each unit of inquiry revolves around.

1.2.2 Definition of Key Terms

The following definitions are used in the research study and are presented to the reader for clarity:

- Project-Based Learning (PBL): is a teacher facilitator, student-centered approach that is considered the heart of a curriculum whereby learning revolves around projects driven

by questions that trigger students' curiosity (Thomas 2000; Kokotsaki, Menzies & Wiggins 2016a; Buck Institute for Education 2019b).

- Rigorous Curriculum Design (RCD): is a high-quality, comprehensive delivery system that serves as a roadmap for teachers whereby the alignment between the fundamental curriculum elements (learning outcomes to assessments, relevant and engaging learning experience, and effective instructional strategies) ensures students' achievement and attainment of required grade or standards within a grade level or subject (Ainsworth & Donovan 2019).
- Measures of Academic Progress (MAP): is an adaptive, innovative computerized assessment that identifies the needs of the students and helps them grow by measuring their achievement in K-12 subjects, particularly science (Cordray *et al.* 2012; NWEA 2012).
- Northwest Evaluation Association (NWEA): is a non-profit research-based organization that provides the MAP assessment to measure students' proficiency and growth (Cordray *et al.* 2012; NWEA 2012).
- Next Generation Science Standards (NGSS): is a K-12 Science education framework that encompasses Life, Physical, Earth, and Space Sciences, and Engineering Design standards that determine what students should know and do by the end of each grade level/cycle through performance expectations that combines the framework's three distinct dimensions to learning Science: Science and Engineering practices, Disciplinary core ideas and Cross Cutting Concepts that constitute every aspect of a learner's life (NGSS Lead States 2013).
- Performance-Based Assessments: are authentic meaningful tasks or learning activities that involve students in a real-world applications whereby they are given a Goal, Role, Audience, Situation, Product, and Standards (success criteria) (GRASPS) through which they are required to demonstrate their knowledge, understanding, and skills through tangible products or performance (Wiggins & Mc Tighe 1998).
- Student-centered: is a form of teaching/learning strategy that puts the students in the center of the teaching and learning process by engaging them through active learning which leads to a higher level of thinking (Kramer *et al.* 2007; Hockings 2009).

1.3 Statement of the Problem

Children show an early interest in science at a young age (Maltese, Melki & Wiebke 2014), but this interest does not last throughout their education (Potvin & Hasni 2014; Shirazi 2017). Teachers' pedagogical choices and how science is presented to students have an impact on students' school science experiences (OECD 2006; Shirazi 2017). Science education is important not only for future Science, Technology, Engineering, and Mathematics (STEM) jobs, but also for preparing responsible and scientifically literate citizens (Krajcik & Czerniak 2018).

The UAE has three entities that manage and control the educational system: ADEK, MOE, and Dubai Knowledge and Human Development Authority (KHDA). These entities focus on student achievements in international and benchmark tests as tools and targets for measuring and evaluating their learners' developmental level and use the data generated from these exams to compare their students' results to other students in other countries (Morgan 2018). While a great deal of attention has been given to improving students' academic skills, knowledge retention, and engagement to achieve UAE national agenda 2071 (UAE Centennial 2071 2022), students are also expected to attain high scores in high-stakes exams. Moreover, although UAE strives to be the world-class education supplier, besides being the best in mathematics, reading, and science and among the twenty highest performing countries in the Programme for International Student Assessment (PISA), its scores in science have been gradually declining year after year (OECD 2019a; Schleicher 2019). Reviewing PISA reports has shown that more than 40 percent of the UAE students are at or below level 2 (proficiency level) in all subject areas (Kamal & Trines 2018; OECD 2019a; Schleicher 2019). While Finland has had a reputation for having one of the best education systems in the world for nearly two decades, its 15-year-olds consistently rank among the top in global PISA league tables for reading, math, and science. This is due to the fact that the Finnish curriculum supports project-based learning as a progressive approach to curriculum and pedagogy appropriate for 21st century learners (Finnish National Board of Education 2016) since the age of seven (Lederman *et al.* 2019).

Moreover, American curriculum schools in UAE have shown a regression in science international test scores compared to their peers in other school curriculum systems (Ina V.S. *et al.* 2015; Lockheed, Prokic-Breuer & Shadrova 2015). This low performance might be due to the lack of motivation and engagement in the learning and assessment process. Therefore, teaching science through projects is seen as a way to keep students interested in science by

allowing them to investigate questions that are close to and meaningful to their lives. According to the Finnish National Board of Education (2016), working methods such as hands-on learning and experiential learning should be used in science teaching. Projects as a method of science learning are not new to education; however, the strength of project-based learning lies in the way all elements of its curriculum work together to promote authentic science learning. Project-based learning assessment plays a pivotal role in assessing the standards by way of increasing the engagement of students in real-life projects. This type of assessment and approach allow students to take ownership in their learning process which will help them construct knowledge and enhance their life skills known as 21st century skills in comparison to teacher-centered approaches (Lenz et al. 2015; Haatainen & Aksela 2021).

While several research papers highlight the importance of studying the effectiveness of designing a contextual, aligned, and flexible curriculum that revolves around PBL especially in science most of the studies that examined the impact of such an instructional approach on students' achievements were mainly conducted in North America, Europe and part of Western Asia such Turkey and Cyprus (Karaçalli & Korur 2014; Nassir 2014; Ayaz & Söylemez 2015; Aidoo et al. 2016; Eckersall 2017; Sahli 2017; Mahasneh & Alwan 2018; Rubrica 2018; Chen & Yong-Cih 2019). In addition, a limited number of research studies investigated the correlation between the impact of using PBL on students' academic outcomes in benchmark assessments (Condliffe et al. 2016; Eckersall 2017) such as MAP tests (Sahli 2017) all over the world. No studies have been carried out in the Middle East (Mahasneh & Alwan 2018) precisely in Abu Dhabi, UAE regarding this, although considerable attention has been given to students' results in the MAP tests.

Additionally, many studies have shown that students who went on to pursue university degrees and careers in science fields are motivated by their curiosity in science, while very few students attribute their sustained interest in science to school, teachers, and classes (Maltese, Melki & Wiebke 2014). A negative experience with science in the school, on the other hand, is more frequently associated with factors such as teachers' pedagogical choices and the manner in which science curriculum content was presented to students (OECD 2006; Shirazi 2017). This demonstrates that, while teachers and schools may not have a significant impact on whether students pursue science-related college degrees or careers, they do have a significant impact on how students experience science in school.

Furthermore, while several factors impact students' outcomes such as instructional timing, subject, location, and technology support (Chen & Yong-Cih 2019), the most pivotal factor is teachers because they are the main point of contact with the students and can cater to their needs in order to deliver instruction and curriculum programs successfully (Hattie 2012; Sahli 2017). While today's teachers recognize that they must adapt and adopt new approaches to keep up with the continuously changing environment of student learning, teachers must employ strategies that support and enhance learner capacity, keeping in mind each student's particular needs, interests, learning styles, and skills. Leaders in curriculum and teaching must determine educational strategies that can deliver the content while also allowing students to develop important lifelong skills that prepare them to succeed in a globally competitive society and help them meet the accountability standards of present-day testing (Whitaker 2019). While previous project-based science learning implementation research has focused on why teachers should adopt PBL or teachers implementing the PBL curricula with some support, there is very little research studies about their perceptions towards their involvement in developing and implementing such curricula in middle school science classrooms.

Therefore, this study aims to investigate the effectiveness of RCD for PBL implementation on middle school science students' achievement in standardized test since this cycle has shown to have the highest impact on college and career readiness (Bender 2019), and MAP scores (as a benchmark assessment) in Abu Dhabi, UAE.

1.4 Purpose and Objectives of the Study

The purpose of this study is to investigate the effectiveness and teachers' perceptions of Rigorous Curriculum Design for project-based learning implementation on middle school science students' achievement and MAP scores in a private school in Abu Dhabi, UAE.

The research objectives of the study are to investigate:

1. the effectiveness of Rigorous Curriculum Design for project-based learning implementation on middle school science students:
 - a) achievement in science standardized knowledge test and
 - b) MAP scores.
2. teachers' perceptions towards Rigorous Curriculum Design for project-based learning development, implementation, and effectiveness in sciences.

1.5 Research Questions

The three main questions that drive this study to shed light on the importance of having a suitable and sustainable curriculum model that is centralized around project-based learning to enhance students' results in the Standardized Science Knowledge test and MAP scores are:

RQ1. To what extent does rigorous curriculum design for project-based learning implementation affect middle school students' achievement in science standardized knowledge tests, in Abu Dhabi, UAE?

RQ2. To what extent does rigorous curriculum design for project-based learning implementation affect middle school science students' MAP scores in Abu Dhabi, UAE?

RQ3. What are middle school teachers' perceptions towards rigorous curriculum design for project-based learning development and implementation in science?

1.6 Rational for the Study

Living in an interconnected world has increased the probability of the risk humanity faces. Although the pandemic (COVID-19) that the world is witnessing is primarily a health crisis, it has impacted all educational sectors, especially curriculum and learning. This has highlighted the flaws in the education system and has given institutions, universities, and schools an opportunity to rethink and re-design their curriculum, instructions, and assessments in a way that upskill students and sustain their motivation (Alqahtani 2020; Schleicher 2020; United Nations 2020).

Ensuring the development and implementation of the RCD-PBL curriculum not only requires aligning standards, instructions and assessment but also centralizes around students while involving main stakeholders such as teachers in its development taking into consideration the culture and context, they live in to draft out a meaningful and authentic assessment that should lead to the desired outcome set by UAE 2021 and 2071 vision.

Referring to Orpwood (2001), a change in curriculum relies on the change in the assessment type and approach. Thus, a change towards PBL whereby students work collaboratively in groups to solve problems and develop products (Kokotsaki, Menzies & Wiggins 2016b) might offer the required level of student engagement and interaction necessary to meet different students' potential achievement levels. In addition, this type of approach might increase students' knowledge retention and academic achievement while ensuring a high quality

of education (Karaçalli & Korur 2014; Nassir 2014; Ayaz & Söylemez 2015; Aidoo *et al.* 2016; Condliffe *et al.* 2017; Sahli 2017; Mahasneh & Alwan 2018; Rubrica 2018; Viro *et al.* 2020) in the Middle East and North Africa (MENA) regions by building and exploring their individual strengths and interests in a well-established curriculum as skills alone are not enough to meet the objectives of PBL (Viro *et al.* 2020). Furthermore, PBL has shown to be a promising instructional and pedagogical strategy for middle school integrated science and is gaining momentum in curriculum reform and educational research studies (Haatainen & Aksela 2021).

Furthermore, to accomplish UAE national agenda 2071 and become a world-class education provider, a lot of focus has been placed on developing students' academic abilities, knowledge retention, and engagement in addition to helping them do well on high-stakes tests. Therefore, achievement-based tests specifically standardized tests and MAP, a key element in measuring educational success and playing a role in determining school ranking, are the tools selected within this study to measure students' current level of ability, accomplishment, and knowledge in Science. While various types of benchmark assessments are currently being implemented in the UAE, Measures of Academic Progress is the most widely and commercially used system that helps students, specifically in the middle school cycle to achieve the required national average of the country and prepare them more for college (Barber 2017). Established by Northwest Evaluation Associations (NWEA) in 1976, the MAP exam is greatly used nowadays by all stakeholders to increase students' growth scores whether in exams or standardized tests. In addition, this exam will give a clear idea on the academic level of each student and monitor their growth and achievement and compare it to that of other students thus, ensuring proper evaluation of the effectiveness of any educational implementation (Torres 2019).

Pertaining to the MAP exam, and despite its nineteen benefits as referenced by educator publications and professional journals (Olson 2007; Ash 2008) the UAE students are still underperforming in it as per reports generated from the NWEA. While students' achievement levels are an important indicator to measure the effectiveness of project-based learning science curricula as compared to textbook knowledge, enhancing students' confidence level is another aspect offered by such curricula as it allows them to transfer and apply their knowledge outside the classroom wall, and face challenges and solve problems set in unfamiliar yet realist situation.

Furthermore, students studying in the UAE have shown low performance and poor results in standardized tests, and as a result, the UAE compiled the perspectives of several external specialists and investigators (Gallagher 2019) towards the needed changes that the country needs to concentrate on. Therefore, according to ADEK, the capital city's local education authority, it has been confirmed that implementing a pedagogical approach such as project-based learning within a high-quality coherent curriculum that aligns between its types (intended, implemented, and assessed) as well as creating long-arching strategies is important in achieving quality improvement in education (ADEC 2012). However, while a limited number of research studies investigated the correlation between PBL science curricula and students' achievements in benchmark assessment (Condliffe *et al.* 2016; Eckersall 2017; Sahli 2017), no studies have yet been carried out in the MENA region specifically in UAE regarding this, although considerable attention has been given towards students' results in the MAP tests.

Subsequently, teachers are considered as one of the most important factors that influence students' learning and achievement (Sanders, Wright & Horn 1997) as they are the mediators that translate the standards into practices as relying solely on standards does not improve students' achievement. Marzano, Marzano, and Pickering (2003) have shown how an effective teacher in a classroom can increase students' achievement by 52 percentile points over a course of a year by defining effectiveness as a combination of a well-established curriculum, appropriate instructional strategies, and classroom management. Therefore, grasping their perceptions towards RCD adopted to design project-based learning curricula units is imperative. To investigate the effectiveness of a suitable and sustainable hierarchical K-12 PBL science curriculum designed by teachers using the RCD on students' achievement is necessary as it should not only meet the cultural and work-driven needs of our community of learners but also bridges the gap between what and how students are learning to how they are applying the knowledge and skills in real-world scenarios.

1.7 Significance of the Study

This research study contributes to the foundational platform for current and future research studies as it will be the first study conducted in the MENA region specifically Abu Dhabi, UAE that investigates the effectiveness of project-based learning science curricula developed using the RCD model on middle school science students' achievement, specifically

standardized science knowledge tests and MAP tests. This study also investigates teachers' perceptions towards the development and implementation of such curriculum.

In addition, as the number of students interested in pursuing science education has dropped dramatically in the last decade (Potvin & Hasni 2014; Al Murshidi 2019), this poses a significant concern for the future of the STEM workforce, since it will become increasingly difficult to fill STEM positions. Therefore, since RCD-PBL curricula investigated in this study is based on the Next Generation Science Standards, this study could be an imperative step that will accommodate for a shift in educational implementation that will ensure the readiness of both teachers and students to handle STEM-based curricula that are mainly based on PBL while raising the engagement and achievement level of students in science classes and external assessments.

Finally, as this study is conducted in an Emirati school in the UAE that is spread throughout five different emirates, the results and impact of this study could be applied and beneficial for other sister schools.

1.8 Structure of the Thesis

The research study is based on five key chapters:

Chapter 1: Introduction

Chapter 1 presents a clear description of the importance of adopting the RCD model as mean to achieving students' science proficiency through serving as a roadmap for teachers, main stakeholders, to designing and implementing student-centered PBL science curricula that align standards, instructions, and assessments. While applying this model to designing curricula units has proven its effectiveness in school districts across the United States and since most of the studies that examined the impact of PBL on students' achievements were mainly conducted in North America, Europe, and part of Western Asia such Turkey and Cyprus, very limited research examined the effectiveness of centralizing such an approach in the curriculum and investigated its impact and effectiveness on students' achievement in the MENA regions. Therefore, our study aims to investigate the effectiveness and teachers' perceptions of developing and implementing a comprehensive PBL curriculum based on the RCD process, in middle school science classes. The latter delivers the content through an effective learning experience taking into consideration the context where students live, allowing them to acquire

the knowledge and skills needed and measuring their achievement through standardized science tests and MAP scores.

Chapter 2: Theoretical Framework and Literature Review

Chapter 2 is divided into two parts, the first part provides detailed information presented to illustrate the purpose of the study clearly and concisely and provide the theories and models that can help direct the course of the study, whereby the second part of this chapter describes and relates recent research studies to the main purpose and constructs of this study mainly: curriculum implementation and reform, project-based learning in K-12 educational settings: inclusion, impact and assessment and teachers' involvement in curriculum planning and implementation.

Chapter 3: Methodology

Chapter 3 outlines the methodology of the research study. The mixed-methods approach is subsequently explored, whereby an explanatory sequential mixed method design is used to collect the data that is used to elucidate and answer the research questions as well as satisfy the research objectives. Several other aspects of the study, which include site selection, instrumentation, population, valid and reliable measurements, and ethical considerations are identified and justified as well.

Chapter 4: Data Analysis and Results

Chapter 4 explains how the data for the research study was collected, analyzed, and reported using both qualitative and quantitative instruments. SSKT scores and MAP scores data were collected from middle school science students. Questionnaire data were obtained from a sample of 25 middle school science teachers and interview questions were transcribed from 6 science teachers that implemented the RCD-PBL curriculum. The quantitative analysis results of the study are presented in the form of graphs and tables. Statistical analysis of quantitative and qualitative data was done respectively using a Statistical Package for the Social Sciences (SPSS) and QDA Miner Lite v2.0.9 free edition respectively.

For RQ1 descriptive statistics on variables were shown and statistical hypothesis tests are used in statistical inference, to decide whether sample data on the improvement in SSKT scores, sufficiently support a particular hypothesis at the 5% level of significance. Also,

Levene's F test for equality of variances and Cohen's d test are respectively conducted to check for the homogeneity assumption. Finally, while an Analysis of Variance (ANOVA) on the mean improvement was carried out to validated and find out if there are any significant differences in mean improvement for the three grades (6, 7, and 8), a two-way ANOVA was conducted to determine the interaction between the grade levels and teaching method and gender on the SSKT mean improvement scores.

To answer RQ2, descriptive and inferential statistics were conducted. Independent sample t-tests were done on the MAP growth for grades 6, 7, and 8. Levene's F test for equality of variances and Cohen's d test for independent sample t-test were also carried out. A one-way ANOVA was also performed on the MAP growth scores for grades 6, 7, and 8.

For RQ3, questionnaire data from Excel extrapolated from survey Monkey was uploaded and coded in SPSS. A reliability test of the questionnaire data was found using Cronbach's alpha. Descriptive analysis was performed, and results were presented as tables and graphs. For the qualitative data from the interview transcripts, thematic analysis was performed according to Braune and Clarke's thematic analysis process then added to the software QDA Miner Lite v2.0.9 for codes, frequency, and percentage calculations.

Chapter 5: Discussion, Conclusions, Limitations, and Recommendations

Chapter 5 outlines the discussion, limitations, and conclusions of the research findings in relation to the aim and objectives of the study. The future implications and related recommendations of the study that may assist other researchers in future studies are presented in chapter 5.

CHAPTER II: THEORETICAL FRAMEWORK AND LITERATURE REVIEW

2.1 Overview

The purpose of the present study is to investigate the effectiveness and teachers' perceptions of Rigorous Curriculum Design for project-based learning implementation on middle school science students' achievement and MAP scores in a private school in Abu Dhabi, UAE. This chapter delivers an overview of the literature which is documented and reviewed to address the focus of the study from various angles that are all linked to the study's purpose.

The first part of this chapter sheds light on the theoretical framework of the study, in order to provide a focus point that will help to find a correlation between the study's theories and models represented by: Rigorous Curriculum Design (RCD), Buck Institute of Education Gold Standard Project-Based Learning model (PBL), and The Next Generation Science Standards Framework (NGSS). It is founded primarily on the constructivist learning theories more specifically Vygotsky's theory of Social Constructivism (1978) and the pragmatic constructivism of Dewey's experiential learning theory (1916).

As this research involves project-based learning whereby the competencies and skills of students are enhanced through active real-world educational experiences, problems, and challenges, therefore, learners need to be involved in hands-on learning projects and activities that relate to their natural environment, their context, and society. Therefore, Dewey's experiential learning theory was used as one of the building blocks that this study depends on.

In addition, this study focuses on investigating middle school science teachers' perceptions regarding the development, implementation, and effectiveness of the RCD-PBL science curricula in enhancing students' achievements in standardized tests and MAP and allows different levels of students to acquire the required knowledge and skills needed by scaffolding, peer tutoring, and cooperative learning through performance-based assessments. For that reason, Vygotsky's social constructivism theory was the second theory adopted, especially since this theory helps in tailoring the design of such curricula to meet the needs of second language learners.

The second part of this chapter illustrates the conceptual framework adopted for this research study. This conceptual framework hinders the factors that contribute to the success of

any curriculum implementation thus leading to proper alignment with its intended and attained curriculum. While several factors influence any curriculum implementation process such as students, school environment, teachers, resources, culture, and assessment are discussed and explained in this chapter, a specific focus is placed on “teachers” as a part of the study revolves around grasping their perceptions towards their involvement in the development and implementation of such curriculum compared to the textbook curriculum in science.

The third part of this chapter is dedicated to the literature review which is associated with the research study’s main constructs, and it provides information about prior studies pertaining to the objectives, gaps in the research line, the methodology adopted along with the process, the significance of the study and finally, key findings. This section is based on four major themes whereby each major theme is divided into subthemes that will influence the study results.

The first major theme addresses curriculum reform and implementation whereby it discusses the importance of quality alignment in the curriculum that leads to an increase in students’ achievement as well as explains and discusses the major curriculum design components. As the study revolves around PBL, the second major theme sheds light on Project-based learning in K-12 educational settings: inclusion, impact, and assessment. This section focuses on clarifying the essential meaning of PBL in the educational field followed by its important role and effect of delivering the NGSS through PBL. The impact of PBL is then reviewed and discussed in relation to research studies done by other authors. In addition, and since reaching the targets of the UAE’s national agenda is fundamental, another subtheme has emerged related to MAP exams and its importance and impact by PBL. Finally, the last subtheme is the type of PBL assessment and its alignment with the curriculum as well as its benefits in second and foreign language settings especially since the participants in this research study are Emiratis.

As the teachers are one of the major factors that influence the success of any curriculum, and since part of the study’s intent is to grasp their perception, the last two major themes discussed in the literature are the importance of teacher empowerment and involvement in curriculum planning and implementation and their perceptions towards PBL.

2.2 Theoretical Framework

This study has its roots in the constructivist learning theory whose principles derive from Dewey's experiential learning theory (Pragmatic constructivism) and Vygotsky's theory of Social Constructivism. While these two main theories are the driving force of the Buck Institute of Education Project-based Learning model, the main components of the RCD framework cross and overlap with it. All these theories and models along with NGSS Framework constitute the main engine of the study and are shown in Figure 1.

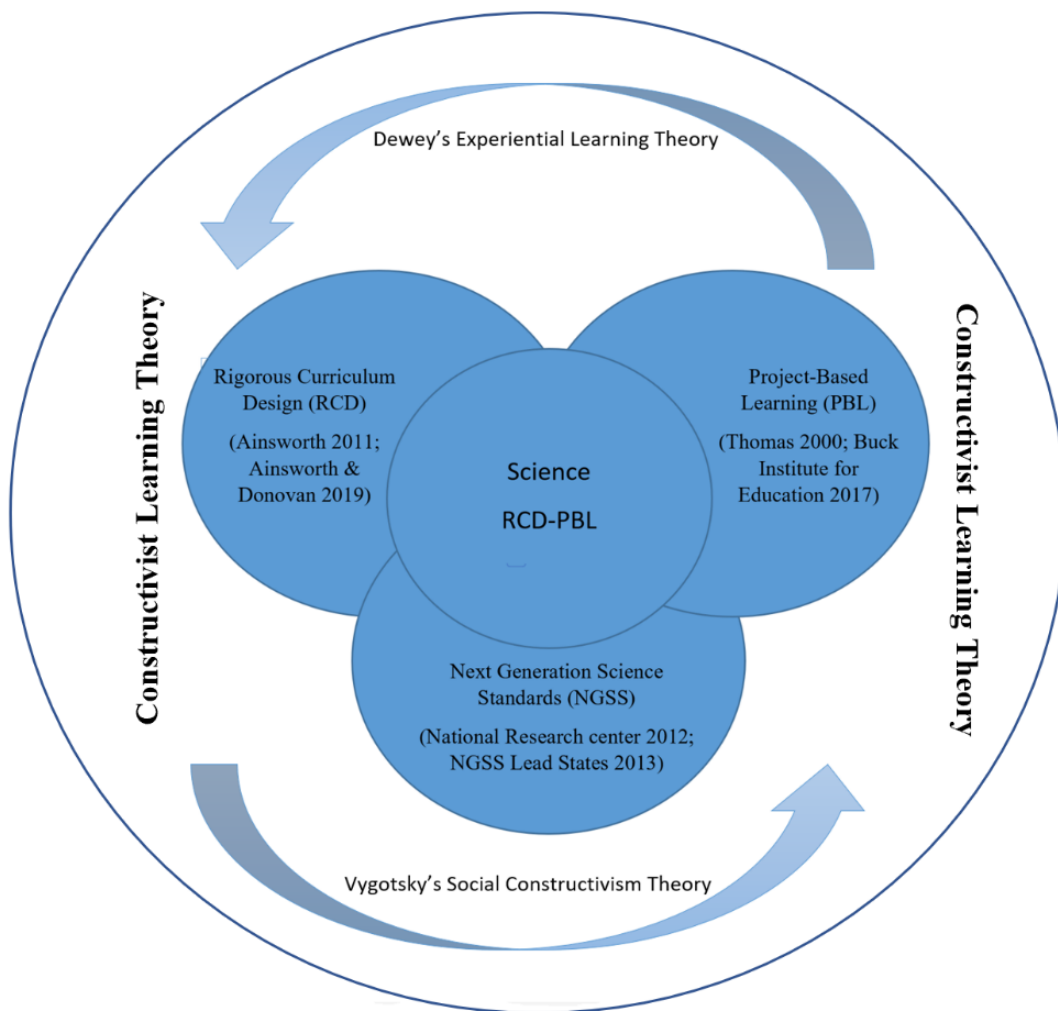


Figure 1: Theoretical Framework of The Study

Constructivism is a paradigm for teaching and learning that directly impacts education as it is primarily based on scientific studies and observations of how people acquire knowledge and learn (Olusegun 2015). Constructivism is considered one of the best strategies in education

specifically in the field of teaching and learning as well as the most powerful 21st century philosophy (Krahenbuhl 2016). This paradigm helps to explain and predict how students difficulties can be eliminated with the help of teachers and other knowledgeable people (O'Connor 2020; Muhtarom, Juniati & Siswono 2021). It is an essential learning philosophy that educators utilize to assist their pupils in their learning and is founded on the premise that individuals actively create their own learning, and that realism is defined by their experience as learners (Richardson 2003). Looking through the lens of a constructivist, learners actively construct knowledge and take ownership of their learning by generating meaning based on their individual experiences and reflections (Bereiter 1996; Richardson 2003). This might result in them changing their beliefs or even discarding irrelevant information whenever experiencing something new as they always need to relate it to their previous experience. Although this teaching and learning approach views learners as active agents, the learning process embedded in this theory is affected not only by the context where the knowledge is acquired by the students but also by students' beliefs (Olusegun 2015). While constructivism rests on the assumption of the current psychology of learning rather than a description of teaching (Fosnot & Perry 2005), the implications of such a theory emphasize on the construction of knowledge through learning outcomes as well as determining learning goals from authentic assessments (Von Glasersfeld 1995). Constructivism is the idea that claims that learners build knowledge rather than merely passively comprehend information. As humans encounter the world and reflect upon certain experiences, they develop their own conceptions and integrate new information within their pre-existing knowledge. In addition, constructivist learning conceptions reside in the works of Dewey, Bruner, Piaget, and Vygotsky whereby learners are urged to be socially and actively involved in the learning process and construct knowledge based on existing knowledge and experiences in order to gain an in-depth understanding rather than relying on memorization (Marlowe & Page 2005) thus shifting from a teacher-centered learning to a student-centered learning approach. Adopting RCD for Project-based Learning that is rooted in the constructivist theory of learning (National Research Council 2012b) revolves around three constructivist principles: (a) learning is context-specific (b) involving students actively in the learning process (c) achieving goals and developing skills through social active learning and interaction. Therefore, this theory is considered the study Global Positioning System (GPS) for which it is used to grasp academic standards (Stenger 2003).

2.2.1 Dewey's Experiential Learning Theory

John Dewey was the founder of the pragmatic pedagogy that was widespread in the United States of America from the end of the 19th century till mid of the 20th century (Nassir 2014). Rooted in the progressive education movement that advocated for additional experiential and student-centered approaches to education, project-based learning endorsed the acquisition of 21st century competencies referred to as deeper learning through active real-world exploration, challenges, and problems (National Research Council 2012b). In democracy and education, Dewey's statement on the experiential learning also known as learning by doing is key to understanding this theory on which instructional teaching methods should be based on: "Give the pupils something to do, not something to learn; and the doing is of such a nature as to demand thinking; learning naturally results" (Dewey 1916, p. 98). Dewey's work has led to several similar approaches known as project and problem-based learning. He believed that learning should revolve around students whereby teachers should facilitate rather than instruct. He offered three principles by which all teaching methods should acknowledge as he believed that education should be communicated through practical experiences and activities going from activity principle to purposefulness of activity, and finally to the connection between activity and life (Dewey 1916). Moreover, he advocated a student-centered learning environment whereby the learning experiences were based on interaction and continuity (Dewey 1938). Additionally, curricula that are sorely based on learning experiences lead to a natural connection between prior and new knowledge acquired (Dewey 1938; Tyler 2013; Sun You 2017). As the learning experience plays a pivotal role in the learning process, curriculum development and design should be interdisciplinary (Nassir 2014) as the world was built upon multiple actions and disciplines and should focus on students' interests and needs (Seaman & Nelen 2011). While both RCD and PBL address students' needs; investigating the effectiveness of RCD for project-based learning should lead to a well-aligned student-centered curriculum whereby students are engaged in relevant, authentic, and meaningful real-world projects which align with Dewey's principles.

However, one of the main problems with constructivist learning is that it is difficult to apply this theory in teaching as it first needs to be incorporated into the curriculum and introduced to teachers (Gray 1997). Teachers must understand and be trained in how to apply this teaching theory in the classroom (Trust & Whalen 2020). One of the teaching methods that

the ideological theory reflects is Project-oriented or Project-based learning (Williams 2017). It is found that project-based learning dates to the 1900s, whereby John Dewey support for the "learning by doing" has reflected the theory of constructivism for which PBL was based on (Jumaat et al. 2017; Niiranen 2021). Dewey explained that learning is a positive and constructive process, not a passive experience, and this requires practical tasks. It is important to understand that project-based learning is added to the students' real situations, which are relevant and authentic (Chen & Yong-Cih 2019). It is noted that project-based learning is a significant method used to find answers to real questions through collaborative research. This forces students to complete tasks or assignments that must be authentic or realistic. On the other hand, reliability and authenticity can be changed with the help of "learning by doing" (Chand & Deshmukh 2019; Van Dun & Wilderom 2021). It is important to help students at the primary level, for example, by asking follow-up questions and recording answers. Furthermore, Dewey has, in particular, pointed out that education is an action that has been used for students' experiences as they are important because they give them meaning (Cox 2018). It is important to understand that new ideas have influenced other researchers because they believe that broader ideas about the development of constructive theory explain how students shape their understanding (Jumaat et al. 2017). Project-based learning requires students to do real activities where they can learn from experience. For this reason, it is believed that students are not considered passive recipients of information and knowledge. It is found that there is a huge link between Dewey's theory and project-based learning for students (Bozkurt 2017). Therefore, Dewey considered the classroom as a "micro-community" where playing, and different activities are considered an essential part of learning communal parts and active participation in the physical atmosphere (Chen & Yong-Cih 2019). Though many knowledge-based environments and project-based learning prospects may be structurally similar, learning ultimately takes place in a teacher-student connection (Al Mamun, Lawrie & Wright 2020). The organization of this union and the school structure was designed by the organizational values that emerged in industrialization near the 1800s when a double revolution in technology and information technology reshaped the United States (Mohajan 2019). As the technological and economic innovations of the Second Industrial Revolution streamlined the technology of production and distribution in the material economy, the modern managerial uprising also introduced novel ways of sending information and communication (Van Dun & Wilderom

2021). At the beginning of the transition from manual production to mass production, the school presented the challenge of harmonizing the social context and restoring skills and concentration in response to dramatic technological changes (Ibn-mohammed et al. 2020). Through a combination of knowledge, skills, teamwork, and communication, project-based learning can help develop thinking habits related to personal and professional achievement in the global economy (H. Fini et al. 2016; Muhtarom, Juniati & Siswono 2021). This type of study includes the elements that motivate good work given that students need an area where they can work to the best of their ability and see the impact of that on the world.

In addition, people demand that learning be seen as a situational activity and that its main characteristics be what is called Legitimate Peripheral Participation (LPP). Therefore, learning is the purpose of any action, the environment, and the cultural values in which it takes place (Nagle 2021). LPP enables students to develop solid and soft knowledge, and it is easy to express and record specific information. Nevertheless, general knowledge can only be acquired through demonstrations or instructions. Students participate in a working community and develop toward full participation in the social and cultural practices of the community (Cox 2018). As a participatory process, LPP offers the opportunity to discuss important connections between new and old members and their activities, identity, knowledge, and practices (Gasson & Purcelle 2018). Through an informal community of teachers based on integrating and maintaining skilled practitioners, it is important to see the skill of craft culture. In society, experienced teachers recognize their talents through stories and help beginners understand their skills in the mood (Vasiliene-Vasiliauskiene et al. 2020). The professional community thrives on war stories of technologists who try to meet and overcome the challenges of technical work. These stories preserve and disseminate hardened knowledge and use it to declare community membership and suitability.

However, it is significant to understand that Dewey did not believe in the ultimate goal of education (Donner & Leahy 2020). He did not set a definitive and ultimate educational goal and used to always talk about short-term goals. For him, education is an ever-changing experience with lifestyle changes. Therefore, the educational process is a continuous process of adjustment in which people always have to adapt to their environment (Nagle 2021). Dewey agreed that the role of education is to prepare for life in the present and the near future. He mentioned that students are not interested in the distant future, and such efforts do not force

them to learn. Education must provide adequate preparation for this life and encourage students to learn. Dewey also agreed to make education a goal of personal development (Ferraris, Santoro & Pellicelli 2020). Dewey believes that the ideal school is the perfect home; therefore, students want elective school to be an ideal community, for example, a family, where students study together (Vasiliene-Vasiliauskiene et al. 2020). Schools should function as one big family, as this will lead to enabling children to be more disciplined at home, with better equipment and more scientific advice and guidance. For instance, Dewey School is a place where ethical education can be shared, not in the form of individual lessons, but collaboration with others (Filho et al. 2020).

Therefore, it is vital for the modern school to give children the opportunity to understand themselves and understand society (Al Mamun, Lawrie & Wright 2020) through a well-established curriculum. Dewey gave teachers an important job and made it their duty to maintain a high level of social order which allows children to grow up in a social environment. Teachers must place more emphasis on student motivation and interest than on teaching. For this reason, the main task of the modern teacher in the UAE is to guide young people toward a successful future. Teachers must help children adapt to current living conditions, as Dewey is a staunch advocate for children's freedom (H. Fini et al. 2016; Nagle 2021). However, this freedom must be controlled and organized by teachers, and it must also be used for the benefit of society. Teachers should not impose their identity or ideology on children. Therefore, teachers in rigorous curriculum design are to choose influences that enrich the child's experience and help it to adapt well. For this reason, teachers must understand the intelligence and temperament of each student to guide them in the perfect direction (Williams 2017; Muhtarom, Juniati & Siswono 2021). However, they need to understand that teachers' own experience, perceptions, and advanced knowledge should enable the student to reach a higher level of development than themselves (the teachers). At the same time, teachers must ensure that individuals and groups live in harmony and, at the same time, prepare the best and most positive students (Mohajan 2019).

According to the study by Holma, Kontinen, and Blanken-Webb (2018), when it comes to discipline, teachers are used to guide children solely on the basis of their richest experience and their most comprehensive wisdom. It is based on the rigorous curriculum design that ensures that children cannot be severely punished (Muhtarom, Juniati & Siswono 2021). Teachers

should encourage self-discipline and share self-discipline. Students must learn to follow their own discipline which must be developed from within (Al Mamun, Lawrie & Wright 2020). Children's natural motivations need to be guided and nurtured through cooperation in schools. This discipline leads to personal development and is not the result of any external or prestigious force (Holma, Kontinen & Blanken-Webb 2018). The teachers' responsibility is to create a suitable physical environment, enrich the children's experience, and work together. As a result, people develop social attitudes, hobbies, and habits (H. Fini et al. 2016). Moreover, Dewey distrusted the traditional curriculum because he could not achieve his upbringing goals. He did not believe that psychology divides the mind into different parts, such as memory, imagination, perception, judgment, etc. (Van Dun & Wilderom 2021). The traditional school curriculum did not take into account the nature of the child, nor did it involve the teacher in its development. According to Dewey, subjects should be based on children's activities (Bozkurt 2017) whereby courses need to focus on communication and future careers requirements that reflects and meet students' individual interests and needs. Dewey believed that children are the ones who thrive in a social environment through their actions. He claimed that the mind was a social construct and that its development depends on social institutions and society (Mohajan 2019; Muhtarom, Juniati & Siswono 2021). Therefore, social experience should be a key factor in learning. Dewey stated that it all started with children's expressive activities based on basic social topics: food, shelter, clothing, and direct social interactions such as talking, writing, reading, drawing, and chopping (Mohajan 2019). Therefore, the basic level needs to be organized according to children's interests in four areas: conversation, research, construction, and artistic expression.

It is important to understand that topics in the traditional curriculum are for informational purposes only (Donner & Leahy 2020). They are neither meeting nor addressing the real needs of the children. Programs and curricula should be based on children's actual experiences, hobbies, and motivations, whereby education is a form of continuous reconstruction and accumulated experience that is rebuilt based on new experiences. According to Dewey, the curriculum should include educational experiences and challenges (Williams 2017). The goal is to enrich the experience gained. The structure of the questions should encourage students to improve their existing knowledge and ideas. It should be noted that Dewey used the term educational experience. This experience, which responds well enough to children's natural tendencies, is only informative in the context of society's social, political, material, and

economic conditions (Van Dun & Wilderom 2021). The educational experience is creative and leads to different experiences, and it can influence future experiences. Textbooks, experience in teacher education, and tools guide students in a natural way towards the social, political, natural, and economic conditions of society. In addition, Dewey came up with proposals for general rules for curriculum development (Filho et al. 2020). Dewey proposed a complete plan based on the principle of importance in the organization of subjects. He argued that when different subjects are taken out of everyday use, each subject connects the subject to the present, and it should be taught in such a way that it underlines its usefulness in modern and daily lives. Therefore, this study tends to investigate the effectiveness of PBL on students' achievement once centralized into the science curriculum using the RCD model whereby teachers' involvement is a critical component.

2.2.2 Vygotsky's Social Constructivism Theory

In recent decades, the work of Lev Vygotsky (1934) has become the basis of many studies and theories of intellectual development, especially those called social culture theories. Vygotsky's socio-cultural theory of learning also known as social constructivism is essential to the instructional enhancement and views human development as a socially mediated process (Stenvall et al. 2018) especially since the construction of knowledge is achieved through active learning process (in Kivunja 2014). In this process, the children acquire cultural values, attitudes, and methods to solve problems through a joint conversation with more informed citizens of society (Alahmad 2020). Vygotsky's theory covers culturally specific instruments, private discourse, and Zone of Proximal Development (ZPD).

The zone of proximal development (ZPD) is one of the most acknowledged Vygotskians' theories that differentiates between two levels whereby learners can move from their actual development level (what they can independently do without any guidance) to their full potential level (what they can do with proper guidance) (Vygotsky 1978). This usually happens using appropriate tools, assistance, and guidance from more experienced partners such as teachers and peers within their communities (Vygotsky 1962). Furthermore, students can reach higher levels through instruction and communication by language which is considered the main tool to influence socio-genetic growth (Scardamalia & Bereiter 1992). Accordingly, the main premise of the constructivist paradigm demonstrates how students develop and build knowledge through active involvement and in their own unique way (Chanlin 2012).

The concept of peer tutoring that is based on the social constructivist view of learning is also important. It is a broad term for a strategy that emphasizes on the role of students in generating learning by having them coach other peers (classmates), who might have comparable or different ranks or skills, through social interaction within their zones of proximal development (Vygotsky 1978). While the act of first education in any skill or subject should be done by the instructor, students may be effective in offering assistance, reinforcement, or modeling for a range of academic topics. The peer tutoring concept allows for many sorts of student pairings (Annis, 1983). Some models link peers of comparable abilities, whereas other approaches pair a higher-performing learner with a lower-performing learner for a target skill. Teachers should pair learners dependent on the skills being covered and, on their behavior, or personality requirements. As learning is enhanced by teaching, this practice is of great importance and rewarding for the tutor student as well (Clarkson & Luca 2002). Through this strategy, students gain access to expertise with the aid of mentors (other students), who serve as facilitators rather than teachers whereby the goal of learning is to solve real-world problems in a genuine context. This is perfectly aligned with the RCD-PBL GRASPS task purpose of our study whereby communications and dialogue between peers in groups help in the construction of knowledge and building of skills. Furthermore, it has been shown how peer tutoring has increased students' engagement in the learning process, enhanced their interest, and improved their achievement and academic skills (Rizve 2012; Ullah, Tabassum & Kaleem 2018; Moliner & Alegre 2020). Thus, this is a very important strategy to consider as it plays an essential role in child development in addition to parents and teachers.

Scaffolding is utilized by Vygotsky to understand the importance of teacher guidance in the learning process that supports the ZPD purpose in reaching the next stage of students' understanding. While teaching using effective student-centered, collaborative and cooperative strategies allows students to gain deeper thinking skills, obtain new meaningful experience, and constructing cognitive internalization of knowledge in students' skills compared to the traditional method (Zulfiqar & Alvi 2019), acknowledging class disparities and differences in terms of culture, language, biological contrasts and personality requires assessment tasks that are meaningful, authentic, whereby students diverse level of understanding can be approached and supported in a unique way (Hoy 2004).

Thus, PBL adopted within the RCD combines theory to experience, and endorses students' knowledge and skills by solving the ill-defined problems through utilizing their cooperative abilities (Capraro & Slough 2013). Therefore, this instructional strategy identifies the multiple potential levels of students which is related to their learning abilities and styles (Ainsworth 2010; Ainsworth & Donovan 2019) and scaffolds students' needs by tailoring them to their current level of understanding (Condliffe et al. 2017). While Krajcik and Shin (2014) and Darling-Hammond et al. (2008) consider scaffolding to be a main component of PBL they believed that it should be faded over time as students learn to apply their new knowledge and skills (Puntambekar & Hubscher 2010).

Vygotsky's theory emphasizes on the fundamental role of social interaction in intellectual development because he strongly believes that society plays a key role in creating meaning. Contrary to Piaget's view that children's development must precede their education (Coats 2019), Vygotsky believed that education is a necessary and universal part of the development of cultural institutions, especially the individual's psychological activities. This means that learning in society is often ahead of its time. Vygotsky emphasized the importance of the cultural and social context in teaching; therefore, it has a solid connection with PBL (Mustafa, Nordin & Razzaq 2020). However, it is important to understand that cognitive development is caused by social interactions that lead to learning in this last area of development, where children acquire knowledge.

According to the theory of social constructivism, the social world evolves through the interaction of individuals with their culture and society. Knowledge is developed in the process of assessing the potential for social negotiation and individual understanding. Every conversation or meeting gives two or more people the opportunity to gain new knowledge or expand existing ideas/knowledges/understanding (Stenvall et al. 2018). Human relations play a role here. In order to apply the theory of social constructivism in education, teachers and school administrators must frequently change their position; both must become experts in education. A good constructive teacher asks students the right or wrong answers to ensure that they understand students' ideas. In addition, teachers should allow students to explain their answers and not allow students to use inexplicable words or equations (Clay & Cazden 2017). They should also encourage students to reflect on their answers.

Social constructivism teaches that all knowledge is the result of social interaction and the use of language, so it is a shared experience, not a personal one (Bozkurt 2017). Observing the world is not the result of knowledge but many social processes and interactions. Therefore, it is believed that constructive learning in the learning process is as important as acquiring new knowledge (Ibn-mohammed et al. 2020). This means that the journey is as important as the destination. The learning process requires students to take an active part in creative and self-organized projects (Coats 2019). Teachers should allow students to ask their questions, present their theories and test their effectiveness (Synytsia 2020).

Furthermore, the gap between the students' current understanding and experience creates an imbalance that forces the student to examine their views and opinions and then experiment with new ideas (Caena & Redecker 2019). Therefore, teachers should encourage students to make mistakes, not reduce them or avoid them (Mustafa, Nordin & Razzaq 2020). Teachers should also use effective assessments such as performance tasks that challenge students to conduct open research and solve problems in a realistic way. Adopting such assessment and projects allow students to explore and point out opportunities for support or conflict. The conflict needs to be researched, clarified, and discussed. Learning is encouraged by reflecting on collected data. A good example of how to resolve conflict is to keep a diary, which often encourages reflection (Rati & Rediani 2021).

Conversations within the public evoked new ideas (Smagorinsky 2018). Anyone interested in the school should view the classroom as a community for discussion and exchange of views. Students in the classroom are responsible for protecting, verifying, substantiating, and communicating their ideas to the community (Synytsia 2020). These ideas can only be accepted as meaningful to society. When they do, they become shared knowledge. Finally, learning does not happen through hearing or sight but primarily through interpretation and hands-on activities, and performance tasks (Handrianto & Rahman 2018). The explanation stems from what is known and develops in the discussion. Project-oriented teaching/learning can be seen as an innovative teaching method that teaches many skills that are necessary for success in the 21st century (Dare et al. 2021). With this teaching method, students can learn to research, work collaboratively in groups on research, and create projects that reflect their knowledge. In addition, project-oriented learning is a holistic teaching method in the classroom that aims to empower students to participate in research on real-world problems (Mustafa, Nordin & Razzaq

2020). Puzzles are another method of group/activity learning. Social constructivism is a theory of learning that views learning as a social process in which students participate in meaningful learning by participating in collaborative projects (Sang et al. 2018). Teachers use methods that enable students to discover and accumulate knowledge as they learn through communication and collaboration (Caena & Redecker 2019). Social constructivism shifts the responsibility for acquiring knowledge from the teacher to the student and transforms students from inactive listeners into active participants and students who create knowledge collaboratively (Malik 2018).

The main concept of Vygotsky's theoretical system is the role of social co-operatives in the learning and development of individuals (Synytsia 2020). Three popular comments on this concept are noted: it emphasizes on the role of society and the group and ignore the role of the individual; it does not solve the problem of the connection between the external world and internal thoughts, it refers to a kind of vague social solidarity, hence this is the social meaning of epistemology (Rahman et al. 2018). These comments indicate the dual polarization of the individual and society. This is due to everyday social interactions and social changes. It is believed that the relationship between society and the individual is a historical process of social and individual development (Handrianto & Rahman 2018). The process of individual development as a society internally through symbolic communication can be summarized as a reconstruction of the ideological aspect, a new understanding, and consciousness based on history and culture. Furthermore, where thinking can create personal understanding, people must be at the forefront of the social community (Baghoussi & Zoubida El Ouchdi 2019). This contradicts Vygotsky's general view that the information refers to the researcher's location. This is important for parenting because exercise has different effects. On the contrary, every role in the development of children's culture takes place twice or occurs at two stages. It manifests itself first on a social level and then on a psychological level (Khasanova & Sanger 2017; Kwietniewski 2017). This manifests itself as a psychological category between people and as a psychological category in children, showing that education should not be limited to the cultural integration of children but should also promote individual awareness through cultural integration (Rahman et al. 2018). This contrasts with the theory of contextual learning, which "shows that learning is limited to the specific circumstances in which it occurs, and that

migration is difficult, if not impossible. The position theory is based on the ideology that unilateral external forces are considered inactive in society (Aldabbus 2018).

In Vygotsky's theory, the main goal of education is to develop knowledge and reason out of context. Second, the ideology of society and the group should not be seen solely as the sum of separate and independent individuals. A philosophical institution whose organization is more than a number of people but still holds the foundation of Vygotsky's theoretical system (Baghoussi & Zoubida El Ouchdi 2019), as each member of the group always contributes at their level and their unique contribution among people in exchange; the number of co-operatives is always greater than the total number of people (Kwietniewski, 2017). For Vygotsky, the connection between shared consciousness and individual consciousness is through shared subjectivity. Historically, compatibility is determined by the co-learner (Admawati, Jumadi & Nursyahidah 2018). The world outside society is not seen as a superstructure, stable and sustainable, but is shaped in history by mutual participation and cooperation (Handrianto & Rahman 2018). The common subjectivity of its members is now the real existence of participation and contribution, which is not only beyond the sum of individual existence, but also has a different nature (Stenvall et al. 2018). Mutual adaptation of culture and values can take place in the school environment. It is pointed out that there are always three active factors: the environment, the students, and the teachers.

Therefore, adopting Vygotsky's theory is essential in tailoring and designing curricula for second language learners as the learning experience delivered through PBL will be based on the environment students live in, which will, in turn help them understand the social and cultural contexts in which they reside, especially since education is explained as being more meaningful, comprehensive (Greene 2005; BAŞ & Beyhan 2010) and developmental through interactive learning (Moll 1990). This socially active interaction improves students' cognitive levels especially since classroom activities and assessments revolve around the concepts extracted from the priority standards that challenge students and allow them to develop deeper understanding through authentic real-world problems projects (Scherba de Valenzuela in Subban 2006). In this regard, the present study is influenced by the social constructivist theory whereby ensuring a set of social active learning will help students improve their achievements level and develop their skills.

2.2.3 Next Generation Science Standards Framework

The Next Generation Science Standards (NGSS) is a K-12 Science education framework that was established based on the National Research Council vision in 2013 (National Research Council 2012a). This framework encompasses three distinct dimensions to learning Science: Science and Engineering Practices (SEP), Disciplinary core ideas (DCI), and Cross Cutting Concepts (CC) that constitute every aspect of our life (NGSS Lead States 2013). The integration of these three dimensions is illustrated in the standards also known as performance expectation (PE) in order to make SEP more meaningful to students by engaging them in practices that allow them to investigate the natural world they live in and provide solutions to real-world problems (Schwarz, Reiser & Cynthia Passmore 2017; Holthuis et al. 2018; *Three Dimensional Learning* 2020).

Shifting towards student-centered learning requires an organized, comprehensive, and cohesive curriculum that engages students in meaningful practices and phenomena exploration and investigation (Holthuis et al. 2018). Stanford University research study team has found that the incorporation of project-based learning that is based on rigorous performance tasks and group work will ensure effective implementation of the NGSS aligned curricula (Holthuis et al. 2018) whereby its three dimensions are not only incorporated in its standards but also in its instructional strategies and assessment (NGSS Lead States 2013). Moreover, Condliffe et al. (2017) have highlighted that the impact of the NGSS in developing students' conceptual knowledge and deepening their skills aligns perfectly with PBL objectives and goals. In addition, these NGSS dimensions along with their alignment with PBL are similar to the scientific literacy key competencies also defined by PISA 2018 (OECD 2019b):

1. Explaining phenomena scientifically;
2. Evaluating and designing scientific inquiry;
3. Interpreting data and evidence scientifically.

Explaining phenomena scientifically demands content knowledge (understanding and explaining ideas, facts, information, and theories) whereby evaluating and designing scientific inquiry and interpreting data and evidence scientifically require both procedural knowledge and epistemic knowledge. Procedural knowledge is referred to as the Know-how knowledge, it represents the common procedures that underlie a variety of methods, operations, and practices to understand how ideas and scientific knowledge are produced. As for the epistemic knowledge

it refers to understanding of the role, constructs, and functions in justifying scientific claims (Yang et al. 2018; OECD 2019b). Therefore, ensuring science proficiency outlined in the PE of this NGSS framework can only happen through assessment that requires students to demonstrate not only factual and content knowledge but understanding and application of the integrated acquired knowledge through engaging science practices (Pellegrino 2013). In this study, NGSS assessments such as standardized tests and MAP are used to investigate the effectiveness of RCD for project-based learning on students' achievement. Finally, all RCD-PBL curriculum units' performance assessment tasks were developed and based on these standards. These standards represent the last symbol (S) in the acronym GRASPS adopted in this study to create authentic assessment tasks. In addition, they are used to develop rubrics and identify the criteria against which the end product will be assessed.

2.2.4 Rigorous Curriculum Design

Implementing a new curriculum model design that encompasses standards, member collaboration, cooperation and rigor will potentially reduce the gap as well as improve students' achievement levels (Jarva 2013). In this study and in response to the implementation of the NGSS, the school in which the study is taking place has adopted a curriculum development process called rigorous curriculum design (RCD). According to Ainsworth (2011), rigorous curriculum design is defined as a high-quality, comprehensive student-centered delivery system that serves as a roadmap for teachers whereby the alignment between the fundamental curriculum elements (learning outcomes to assessments, relevant and engaging learning experience, and effective instructional strategies) ensures student achievement and attainment of required grade or standards within a grade level or subject. It has been shown that student-centered design curriculum also known as learner-centered curriculum leads to high student achievement in different cycles and subjects such as Mathematics, English, and Science (Polly et al. 2015; Üzümlü & Pesen 2019).

Ensuring quality education and promoting lifelong learning skills can only happen through a well-established curriculum that bridges between education and the development of competencies (Philip 2016). Ensuring a world-class education system that meets or surpasses international standards, private schools should design curricula units that strategically and thoughtfully place and align all curriculum pieces together (Horton & Chambers 2013, ADEK 2020b). Therefore, designing a high-quality student-centered curriculum based on the RCD

model should provide a coherent, cumulative, and well-sequenced enriched curriculum that deepens and broadens with each grade level (Pondiscio 2020) and allows educators to meet the challenging learning needs of students and ensure their proficiency in high-stakes tests.

This model starts by building the foundation of a grade-level curriculum through prioritization of the standards to be addressed according to topics to view through a conceptual lens. Followed by unwrapping the standards to determine the topical big ideas that are derived from the concepts (nouns) of what the student needs to know and the cognitive level (rigor) for each skill; what the student will be able to do. Subsequently, creating scope and sequence which is also known as a pacing guide for the unit developed. Beginning with the end in mind is very important as creating units' assessment based on standards followed by creating units of study that encompass rigorous and engaging learning experiences is fundamental to achieving the required results. The urge for a comprehensive and cohesive curriculum that firmly and intentionally connects standards, instruction, and assessment has never been more needed than it has today. Furthermore, this model has the project as its core engaging learning experience that incorporates attributes such as authenticity, relevancy to life situations and contexts, interdisciplinarity, mental stimulation, motivation, technology, collaboration, and individual work. In addition to reasoning, application, analysis, synthesis, creativity, self-assessment, and reflection (Ainsworth & Donovan 2019). Intentionally connecting standards, instructions, and assessment can happen through centralizing the RCD units of study by adopting PBL whereby their inclusion with NGSS framework delivery and assessment has been fruitful (Holthuis et al. 2018).

2.2.5 Buck Institute of Education Gold Standard Project-Based Learning Model

Project-based learning is a teacher facilitator, student-centered approach that is considered the heart of a curriculum whereby learning revolves around projects driven by questions that trigger students' curiosity (Blumenfeld et al. 1991; Thomas 2000; Kokotsaki, Menzies & Wiggins 2016a). To capture the uniqueness of this approach, five criteria were stated by Thomas (2000): Curriculum core, driven questions, constructive investigation, autonomy, and realism. According to Thomas (2000), PBL is central to the curriculum and not peripheral whereby the project is the core teaching strategy that delivers the concepts needed to be taught in a discipline. Although several strategies and instructional approaches exist such as inquiry-based learning, learning by design, and problem-based learning, the differences between them

should be identified especially between the concepts of project and problem-based learning (Savery 2019). While scholars have acknowledged that problem-based learning is a type of PBL (Condliffe et al. 2017), unlike problem-based learning, Savery (2019) has indicated that PBL requires constructing and delivering a product that addresses the project's main purpose.

These projects are chosen based on students' interests and are driven by questions or problems that allow students to learn the central principles and concepts of a discipline. Students will construct their knowledge through constructive investigation that is based on a Goal, Role, Audience, Situation, Product, and Standards (GRASPS) since choosing the right approach promotes self-learning, motivates the students, and gives them room to be more independent (Aldabbus 2018). Moreover, these authentic projects ensure student autonomy, accountability, authenticity, reflection, voice, and choice as they are mostly student-driven and related to real-life topics and problems (Buck Institute for Education 2019b). Compensating these criteria makes a project a PBL whereby skills development and knowledge acquisition in K-12 classrooms are based on students' engagement, collaborative learning, and scaffolding (Condliffe et al. 2016). Students manifest their learning through tackling a project that leads to creating and presenting a product that addresses a main problem or challenge that they are currently facing in the world. These projects differ from regular projects that are usually performed at the end of the academic year or term by not being restricted to one pathway decided in advance by their teachers (Aldabbus 2018). Finally, Students' reflections are carried out throughout the process in addition to teachers' feedback.

To ensure effective PBL usage and application, Buck Institute for Education (BIE) has created a comprehensive guiding model entitled "Gold Standard PBL" to help teachers and schools design, improve and measure their practices by promoting 21st century teaching and learning and assessing students' knowledge and skills through projects (Rubrica, 2018; Buck Institute for Education 2019b, 2019a). This guiding model encompasses seven essential project design elements, shown in Figure 2 all centrally based on students learning goals of the reflection (key knowledge, understanding, and success skills) (Larmer, Mergendoller & Boss 2015; Buck Institute for Education 2019a):

1. Challenging problem or question: the heart of any project whereby problem or questions to be addressed are at the appropriate level of challenge, student-friendly, open-minded, and meaningful.

2. Sustained inquiry: rigorous inquiry cycle process and starts with students posing questions, finding resources, asking deeper questions, and applying information until an adequate solution is reached. This highlights that a true PBL project lasts more than a few days.
3. Authenticity: projects that are genuine and meaningful motivate students to learn and connect them to their environment and communities especially when they revolve around real-world context, quality standards, impact, tasks, and tools or speak to personal interests and concerns.
4. Student voice and choice: student's engagement increases as they take ownership in the project whereby they express their ideas in their voices, make informed decisions, develop questions, find resources, and set a work plan that highlights how they work and create their final product.
5. Reflection: reflecting on the learning journey (what, how, and why they are learning) allows students to overcome the obstacles faced in the project, improve their future strategies and help them envision the application of knowledge and skills in another context. Reflection happens from both sides (teachers and students) which helps improve PBL practice quality.
6. Critique and revision: students should give and receive constructive feedback through multiple sources (teachers, peers, and experts) and be given time to apply this feedback to adjust and improve their work processes and products.
7. Public product: students share, explain, and present their products to authentic audiences beyond their classrooms which helps increase the quality of the work submitted and create a learning community. This element encompasses the PBL authenticity criterion.

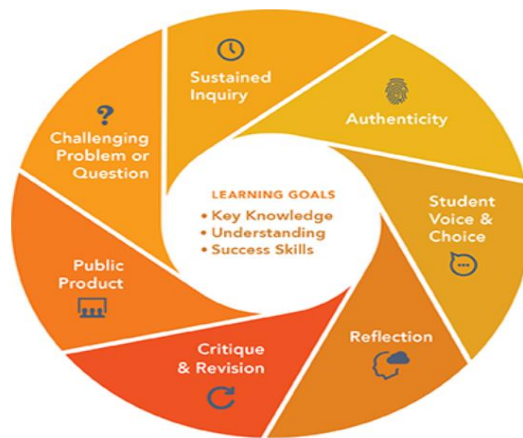


Figure 2: Gold Standard PBL Essential Design Elements

(Buck Institute for Education 2019a)

Referring to Larmer, Mergendoller and Boss (2015) description of the “Gold Standard PBL” on the BIE website, a well-designed PBL curriculum should highlight the importance of concepts, content standards, and in-depth understanding of school courses and disciplines. Furthermore, Krajcik and Shin (2014) pinpointed the importance of designing such curricula around clear learning outcomes that align with national standards, especially in science whereby the NGSS PE are the learning performance that brings the core ideas to the key practices and crosscutting concepts (NGSS Lead States 2013; Marzano, Yanoski & Paynter 2016). While RCD has engaging and authentic learning experiences as its core, its attributes are incorporated within the learning experiences (Eckersall 2017; Sahli 2017; Ainsworth & Donovan 2019) and are aligned and overlap with the BIE Gold standard PBL model. Thus, the RCD will be a collection of PBL units. Finally, developing PBL units by adopting the RCD student-centered model for the middle school science curriculum is important as this cycle has shown to have the highest impact on college and career readiness (Bender 2019).

2.3 Conceptual Framework

Project-based learning is grounded around cross-cutting essential elements that outline how and what students should be taught and evaluated (Condliffe et al. 2017). Based on the constructivist learning theory, this approach shifts the curriculum from transmission (passive learners) to a transactional (active learners) type allowing students to reach and acquire new understanding (Gray 1997). Centralizing this approach into the curriculum requires the alignment of its three sequential consecutive types: the intended, implemented, and attained

curriculum (Porter 2002; Van den Akker 2003). The different levels and alignment between these elements as described by van den Akker and Voogt (1994) was adopted as a conceptual framework as it leads to the required outcome and goal achievement of this curriculum. The intended curriculum is based on the described content standards and objectives for a specified subject and grade level which in our study is based on the NGSS's latest science education reform document (Kuiper, Folmer & Ottevanger 2013). The implemented curriculum, also known as enacted curriculum, (how and what the teacher teaches) comprises the instructional strategies, content, learning experience, and time allocated to the classroom instructions and activities (Phaeton & Stears 2017). This element of the curriculum is viewed in two forms: while teachers' opinions, beliefs, and understanding of the core element of RCD (standards, instruction, and assessment) constitute the perceived curriculum, the implementation of the practices of teaching and learning based on PBL in the classroom constitutes the operational curriculum (Van den Akker 2003). Finally, the attained curriculum which encompasses the experiential results achieved by students as a result of alignment between the intended and implemented curriculum (Van den Akker & Thijs 2009) will be evaluated through science and MAP test scores and growth.

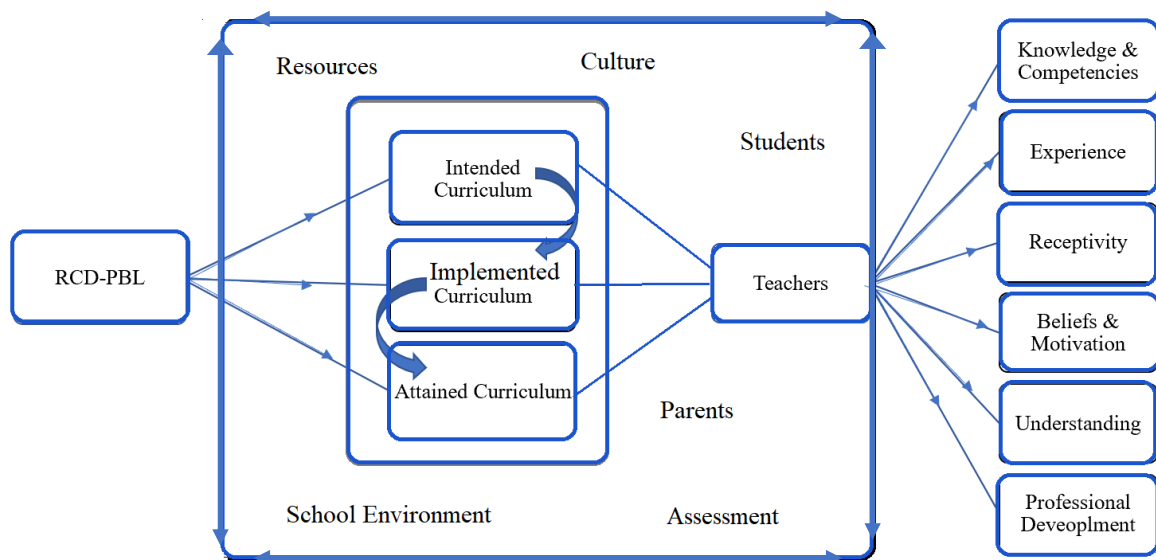


Figure 3: Conceptual Framework

Ensuring a high-quality curriculum is centralized around teachers' voice and involvement in the development of any curriculum (Alsubaie 2016; Kizkapan & Bektas 2017; Bediako 2019) especially since they are an integral part of the environment that affect a curriculum (Carl 2009a) and how a subject such as science is perceived by students. In addition, teachers' knowledge, competencies, and experience are valuable and essential to meeting the learners' needs (Bediako 2019; Haatainen & Aksela 2021). While curriculum implementation is affected by several factors (Figure 3): teachers, resources, school environment, culture, and assessment (Bediako 2019; Yokom 2020), this study mainly focuses on grasping teachers' perceptions towards designing and implementing PBL science units using RCD model. In addition, this study acknowledges that teachers are the key agents that put the curriculum into operation and ensure a natural synergy and alignment between its three types (Luciano 2014; Bediako 2019). Finally, centralizing the curriculum around PBL is one of the most difficult yet important aspects of designing a successful approach (Condliffe et al. 2017), whereby carrying out its development and implementation effectively depends on the teachers' capabilities (Knowledge, competencies, and experience), motivation, receptivity, and understanding of a curriculum and professional development (PD) (Handler 2010; Luciano 2014; Han et al. 2015; Alsubaie 2016; Capraro et al. 2016; Viro et al. 2020; Haatainen & Aksela 2021). While a gap exists between understanding of PBL and the ability to implement it with fidelity in the classrooms (Han et al. 2015) it has been strongly suggested that teachers undergo professional development that will help align their beliefs with the PBL approach and give them the pedagogical skills needed to design and implement such changes in their practices (Capraro et al. 2016).

It is important to understand that the role of the teacher is significant for students. Research studies have shown that students who are interested in a particular topic because they like a particular teacher are more willing to learn the subject and show a higher level of enthusiasm, more dedication, greater attentiveness, and a better approach to the learning process. Attitude, tougher perseverance, stronger courage, and determination to overcome difficulties; nearly all teachers have faced such a problem and regard it as an achievement in their own tutoring, from which they feel the wisdom of accomplishment and pleasure of being a teacher. The teacher-student bond affects more than just student performance. Nearly all outstanding teachers have a major role in building a harmonious teacher-student relationship.

They can establish a close relationship with their students and their speech, words, and behavior can leave a mark and play a lasting role in students' hearts, thereby affecting the development of students' feelings, attitudes, and morals (Ahmed & Opoku 2021).

Of course, it is very important for teachers to introduce interesting content and subject charm in their teaching subjects. Some teachers often use exciting experiments to appeal to students and excite their interest in learning, and these practices have certain effects. At the same time, the way a teacher introduces themselves or the course is equally important as it can show confidence, competencies, and dedication to the subject (Dignath & Büttner 2018). Moreover, the very first impression a teacher makes is even more critical. Teachers usually meet students, greet them enthusiastically, and exchange a few warm and caring welcoming words, which is also an effective way to enhance the relationship between teachers and students.

It is significant to understand that there are different factors that can affect the curriculum of students. It is noted that intelligence factors are also called cognitive factors. The level of intellectual development is very important for knowledge teaching (Cox et al. 2019). Many psychologists have conducted a lot of statistical analyses on the relationship between intelligence and learning effect and found that there is a clear correlation between the two. This means that intelligence is an important factor that affects knowledge learning (Dignath & Büttner 2018). It is generally believed that the factors that constitute intelligence include observation, memory, thinking, and imagination. Non-intellectual factors are also called non-cognitive factors. Non-intellectual factors mainly refer to motivation, interest, emotion, will, and character. With a certain structure and function, non-intellectual factors mainly play a role in motivation, orientation, maintenance, adjustment, and reinforcement in the learning process of students. Students with normal intelligence often have different learning effects due to the different progress of non-intellectual factors such as emotion, will, character, temperament, motivation, and interest. Experts believe that non-intellectual factors have a greater impact on student learning efficiency than intellectual factors (Liu, Fan & Wang 2021).

Moreover, there is a close relationship between students' learning, learning motivation, and teacher motivation (Magson et al. 2021). Learning motivation is the basic factor that constitutes enthusiasm for learning, and it is an internal motivation that directly promotes students' learning. Motivation and learning typically have a complementary relationship. Motivation promotes teaching and learning in a way that enhances behavior, and the knowledge

learned in turn enhances learning motivation. The research of psychologists at home and abroad proves that the main motivation of students in classroom learning is mainly reflected in achievement motivation. Achievement motivation is generated based on people's achievement needs. It is an internal driving force that encourages individuals to be willing to engage in work that they consider important or valuable and strive to achieve success (Le & Lei 2018). In learning activities, achievement motivation is one of the main learning motivations. Teachers can help students obtain higher achievement motivation by stimulating students' interest in learning and curiosity. Some students might lack the motivation to learn due to problems in their society, at school, or at home. It may also be that some students have formed the wrong motivation for learning, which in turn affects their learning abilities.

Personality refers to the comprehensive psychological characteristics that determine an individual's explicit behavior and implicit behavior and make it steadily distinguished from the behavior of others (Kurdi et al. 2019). The so-called adaptation generally refers to the relationship between the individual and the social environment. If a student can carry out various activities normally and can actively explore various learning problems, then he has a healthy personality that adapts well. The opposite of a well-adapted healthy personality is the maladjustment of the personality. The so-called maladaptive personality refers to the various emotional disturbances that prevents individuals from adapting to the requirements of the environment or actively acting on and reforming the environment. Students' personality maladjustment is closely related to their learning efficiency (Blau, Weiser & Eshet-Alkalai 2017). Personality maladjustment is often manifested as low attention span, hyperactivity, deliberate disturbance, and personality immaturity, etc. These problems will hinder students' learning efforts and distract students from learning. Therefore, students with maladaptive personalities lack confidence in learning and often avoid learning difficulties. Some students even appear to be opposed and uncooperative with their teachers. From a long-term perspective, these problems will affect students' learning efficiency. Therefore, a healthy personality is an indispensable foundation for students to carry out effective learning.

A harmonious teacher-student relationship is a prerequisite for a high-quality class. Only by developing friendship with students, can a teacher fulfill their mission/purpose (Casson et al., 2019). Education should first be warm and human. Love and enthusiasm can inspire responsibility. Loving, respecting, and communicating with students allow them to better know

their teachers and believe in them (Casson et al., 2019). Therefore, teachers should dig deep into and understand students' interests, hobbies, changes in emotions, as well as care for, respect, and help students in a targeted manner. Of course, this does not imply that their shortcomings cannot be criticized.

On the other hand, higher education institutions are carrying out various actions to support the improvement of academic performance and prevention of student dropouts. The transformation of the service offered to higher-level students and tutoring has been proposed as an accompaniment and teaching support of an individual nature (Rivera-Vargas, Anderson & Cano 2021). Through tutoring, the teacher can achieve a better understanding of the problems that the student faces in their adaptation to the university environment, of the individual conditions for an acceptable performance during their training, and of the achievement of the academic objectives that will allow them to face the commitments of future professional practice.

All these actions are important and transformative in higher education as they improve performance and efficiency in undergraduate degrees, as well as increase retention, graduation rates, and degrees. However, it has not yet been considered relevant to include the exploration and study of the families of university students. It would be convenient to include the family context as a promoter of the academic development of the students since there is a positive relationship between the expectations of the students and their family's expectations regarding their studies (Dignath & Büttner 2018). The way in which the family context can be made to contribute to school success is perhaps through courses or workshops for students and parents, in which topics that benefit family relationships, communication, problem-solving, and others are addressed. It is important that links are established between the universities and the families of the students to contribute to the benefit of the educational activity of university students and contribute to curbing the most serious problem.

Furthermore, school performance is seen as a psychosocial process embedded in history and culture in which contextual and social variables are included, which within positive and developmental psychology are considered as institutional resources and would be school environments and relatives. The school environment consists of the perceptions that students have about the socio-psychological context in which learning occurs and is obtained. When it is healthy, and teacher morale is high, teachers feel good about themselves, that is, with an

educational environment characterized by a positive climate between teachers and students (Frenzel et al. 2018). In the educational field, different contexts have been studied and analyzed with different scales and instruments that mainly deal with the direct relationship between a positive school climate and academic variables such as school performance, the acquisition of cognitive skills, effective learning, development, positive attitudes towards study, among others. Undoubtedly, home is the first school of a child; it is where the first notions of life are acquired, values are instilled, and a path is prepared for the child to face the challenges both in school and in life (Blau, Weiser & Eshet-Alkalai 2017). Indeed, a good parent-child relationship results in a good positive family environment. Consequently, one of the factors that make up a positive family environment is good communication between the family, since it has been shown that the better the communication between parents and adolescents, the more likely it is that conflicts will be resolved.

Undoubtedly, the teacher is the most important agent in the implementation of the curriculum. Therefore, with the help of their knowledge, experience, and skills, teachers are the core of the curriculum design of any subject. Teachers promote better learning because they know the best teaching methods and are responsible for the lessons in the classroom (Gunawan 2017). After a peer has developed a program, the teacher must strive to understand and comprehend it. Therefore, teachers should be involved in the development of the curriculum. As teachers must be involved in curriculum development, they must have the appropriate knowledge and skills to take on an active role in curriculum development. Therefore, teachers need training courses and workshops to assist in curriculum development. On the other hand, for teachers to be able to take an active part in curriculum development, it is also very important, that teachers be given power in curriculum development (Chan et al., 2017). This means empowering and improving teachers in various ways, such as experience and autonomy. Therefore, the teacher plays an important role in the curriculum development process and the matriculation examinations.

Teachers have many roles and responsibilities in creating a curriculum. Teachers want to enjoy the teaching and see students develop interests and skills in areas of interest. Teachers can contribute by organizing and writing textbooks, and working effectively with curriculum development teams and experts (Handelzalts 2019). It is important to include teachers in the curriculum development process to align the content to the needs of the class. It is noted that

belief refers to the subject's belief in certain theoretical principles and ideological insights of nature and society without a doubt. Psychological activities have far-reaching influences, which determine the principle and tenacity of a person's behavior. Behaviors guided by beliefs can often be observed, but beliefs and values exist in the consciousness, and most of them are in the subconscious. It is controlled by the subconscious like a huge computer program, our brain can automatically think and make the necessary reaction, which people do not notice easily (Amon 2018). Therefore, beliefs and values are often ignored by people.

Educational activities are man-made social practice activities, which are full of value and exist for the realization of certain value pursuits. In daily work environment, regardless of whether they are aware of it or not, teachers are always making various choices, and under the guidance of their beliefs, they carry out various educational practices. According to Kochneva et al. (2020), teachers' beliefs are the most valued characteristics of a school. The knowledge of this will almost become the only task in classroom teaching. Delving into the teaching materials and carefully arranging every link in the teaching process is the basis of teacher preparation. The teacher's ability to execute the course is to ensure that the teaching plan can be carried out on the predetermined track and achieve the expected goals and outcomes.

The basic education curriculum reform puts forward new requirements on what and how to teach students, and it will inevitably require teachers to make great changes in their daily teaching behavior. It is believed that curriculum implementation includes at least three levels of changes: changes in curriculum materials, teaching practices, and changes in beliefs about curriculum and learning (Zhou et al. 2020). The latter two levels refer to teachers' external behavioral changes and internal psychological changes, while the first level is the extension and materialization of teacher changes. Among these three levels, teachers' beliefs are the most important and the most difficult to change. In theory, replacement with a new set of curriculum materials is the most common way to change, and it is also the easiest way to proceed. This is because the changes in the course materials only know the "what to do", and the changes in the teaching practice triggered are to know the "how to do". The formation of new methods and conceptual understanding of "what", "why to do" and "to what extent" reflects a fundamental change (Honig, Venkateswaran & McNeil 2017). The basis of change lies in the fundamental change of beliefs. Only when these assumptions and beliefs are questioned, challenged, or replaced can real changes occur. If the teacher does not agree with the concept of the new

curriculum, does not understand the purpose and connotation of the new curriculum, and does not change the original beliefs, the curriculum cannot be truly implemented, and the implementation will be half the result due to the lack of the guidance of correct beliefs.

Teachers' emotions belong to the category of spiritual activity, which is a natural response to complex emotions such as happiness, anger, sorrow, and happiness caused by external stimuli or internal physical conditions (Aguilar 2018). Emotions start from certain internal and external stimulus situations, and there are different emotional manifestations and behavioral responses due to different perceptions, cognitions, and feelings of individuals. This means that emotions are often accompanied by emotional experiences of physical and psychological changes, and this experience is often not controlled by consciousness or reason. It is often said that emotions are uncontrollable as the weather and can greatly affect us. Emotions are roughly divided into positive emotions and negative emotions. The positive emotion dimension reflects the degree of individual experience of positive feelings, such as happiness, interest, enthusiasm, and other emotions, whereas the negative emotion dimension represents the degree of individual experience of a certain negative or disgusting emotion, such as tension, sadness, annoyance (Hu et al., 2019). People are always expected to show positive emotions and suppress bad emotions in activities. In order to fulfill the expected role, the process of adjusting, managing, and expressing one's emotions in a manner that meets expectations is regarded as emotional labor. In the state of emotional labor, emotion is no longer an individual's personal feelings. When an individual enters the public sphere, he/she accepts the domination of factors related to the organization's interests.

Teaching activities are emotional in nature. As a member of staff engaged in teaching activities, a teacher is an emotional worker as is determined by the professional characteristics of the teacher. The curriculum reform has launched an all-round impact on traditional basic education with a nearly new face, exaggerating the ideals of democracy, science, progress, and full of humanity (Lee 2019). Reform means breaking the norm, changing the living environment, behavior patterns, role positioning and ideological concepts that people are already familiar with, and impacting the "self" consciousness of people in the whirlpool of reform. Facing these changes, teachers need to constantly reshape the boundaries of self-things that were originally considered and utilized, and needs to accept, adapt and integrate the new factors. The self is the habitat of emotions, just like our senses, emotions embody and convey

information about the self. When the emotional overload is running and the pressure reaches a certain level, the individual first adopts an unrealistic mode of thinking. This mode of thinking is often illogical and unreasonable thoughts, which can cause people to feel fear, worry and anger, and thus derive inappropriate actions (Yin, Huang & Chen 2019). The result is low work efficiency and poor results, and the thoughts affect their emotions.

Finally, given that teachers are one of the main factors that have a significant effect on the success of the curriculum implementation as well as students' outcomes, grasping their perception through a questionnaire and interviews is pivotal to evaluate their involvement, preparation, and challenges they face when placing these RCD-PBL curricula into practice. In this study, and as discussed earlier in this section, the researcher will focus on the five main constructs below that influence the effectiveness and the success of any curriculum implementation:

- A. Teachers' qualifications: subject knowledge, competencies, and years of experience that teachers possess along with their degrees.
- B. Receptivity: expresses the value, practicality, and relevancy of a curriculum beside the confidence of teachers towards its implementation.
- C. Motivation: specifically, intrinsic motivation whereby teachers would step forward and have the willingness to participate in a professional development and curriculum development which aims toward the successful implementation of a curriculum and enhance students' achievements.
- D. Understanding: teachers' understanding of the alignments between standards, instructions and assessments adopted and based in each curriculum unit of study based on RCD-PBL.
- E. Professional Development: professional and continuous training and workshops that develop teachers' knowledge and improve their skills to address students' learning challenges, raise their achievements as well as ensure teachers' readiness towards the implementation of any educational intervention.

2.4 Literature Major Themes

One of the most difficult aspects of education is to nurture and raise new generations capable of effectively contributing to the shaping of the world's future (Thomas & Jose 2018). Designing and implementing a contextual, aligned, and flexible curriculum that revolves around

PBL should meet the work-driven needs of second language learners. In addition, learners should be engaged in the learning process and assessments that provide and prepare them with all the necessary reasoning skills that will enable them to become effective pioneers and participate later in the learning economy (UAE Ministry of Cabinet Affairs 2015). Furthermore, as stated by Marzano, Marzano, and Pickering (2003) and Mantra (2017), students' achievements, curriculum effectiveness, and proper implementation depend mainly on teachers' knowledge, involvement, and readiness. Therefore, for the purpose of this study, four major themes were reviewed and selected from the literature, which are: curriculum implementation and reform, project-based learning in K-12 educational settings, teachers' involvement in curriculum planning and implementation, and their perceptions towards PBL.

2.4.1 Curriculum Reform and Implementation

The evolution of Arab countries curricula has been influenced by the western countries' reform as advocated by Dagher and BouJaoude (2011). For instance, Saudi Arabia and Bahrain have adopted the science curricula published by a US company, McGraw-Hill (Obeikan 2010). In addition, the Ministry of Education in the UAE has adopted a science curriculum developed by an American publisher, Harcourt as mentioned by Al Qasimi (in Al-Sebaei 2013), and has partnered with McGraw-Hill for seven years to develop science and mathematics curricula (Sahoo 2016). However, the culture, society, and learning experience of students in MENA regions are different from those in western countries (Dagher & BouJaoude 2011). Transferring science-related materials and learning experiences to second language learners within a western context will neither lead to an increase in the students' outcomes nor will it allow students to transfer their understanding of scientific knowledge and skills into relevant and meaningful learning experiences as it does not relate to the phenomena nor the culture that surrounds them (Kawagley, Norris-Tull & Norris-Tull 1998). This is shown in the PISA 2018 results whereby 55 % of students of the six MENA countries (Saudi Arabia, Morocco, Jordan, Lebanon, Qatar, and United Arab Emirates) are poorly performing compared to other international countries (Schleicher 2019). This research will focus mainly on the UAE whose results are declining gradually in science on each PISA assessment (OECD 2019a) and lacks overarching curriculum documents that align, standards, instructions, and assessments compared to the majority of the OECD (Ridge, Kippels & Farah 2017). Thus, to better understand and ensure proper curriculum

reform and implementation, two subthemes related to its quality alignment, achievement, and design components are discussed under this major theme.

2.4.1.1 Quality Curriculum Alignment and Achievement

Incorporating alignment and coherence in a curriculum design, especially student-centered, is important as it ensures that standards (written curriculum) and assessment (tested curriculum) are tackled in the instructional process (taught curriculum) leading to improvement in students' achievements (Ainsworth 2010; Squires 2012; Fortus et al. 2015). In his book, Squires (2009) has discussed the powerful implication of aligning standards, instruction, and assessment in improving students' achievements and school performance. Moreover, he evaluated several curriculum designs such as learning goals-driven design model in the context of Investigating and Questioning our World through Science and Technology (IQWST) by Krajcik, McNeill, and Reiser (2008), course design by Posner and Rudnitsky (2006), understanding by design by Wiggins and McTighe (2005), the concept-based curriculum by Erickson (2001) and more whereby he highlights the positive effect of such high-quality curriculum design on students achievement. However, one common drawback that has been commonly observed across these designs is that they neither addressed nor provided a roadmap on one important dimension which is alignment. Although the alignment between the curriculum core elements increased low and high-aptitude students' test scores, the efficacy of curriculum alignment is not widely studied in the literature (Squires 2012). This point has been raised and emphasized by Fortus et al. (2015) who identified that students' achievement is hindered by achieving curriculum coherence between its four levels: standard content, learning goal, inter and intra unit coherence. The learning goals and content coherence synthesized from the standards refer to the sequence and depth of curriculum content knowledge and skills on which students build on and develop as they move from novice to expert level through a curriculum. Inter and Intra curriculum refer respectively to the alignment between the curriculum core elements, standard, practice, and assessment and their relationship across units which reflects the Larry Ainsworth RCD purpose. In addition, Krajcik, McNeill, and Reiser (2008) learning goal design model has highlighted that combining standards to PBL pedagogy within this model relies on three important features:

- 1) unpacking the standards, specifically science;
- 2) developing learning performances approach to denote learning targets; and

3) aligning learning goals, teaching and learning instructions, and activities to assessments.

The following elements constitute the foundation and designing parts of the RCD whereby prioritizing and unwrapping standards, writing big ideas and essential questions, creating pre-post assessments, setting authentic performance tasks, planning relevant and engaging learning experiences, and using appropriate instructional and pedagogical approaches and strategies to meet the students learning needs (Ainsworth & Donovan 2019). Furthermore, this building foundation and design elements of RCD incorporate the Understanding by Design (UbD) model's three stages within its parts: identify desired results, determine assessment evidence, and plan instructions and learning experiences (Wiggins & Mc Tighe 1998; Wiggins & McTighe 2005; Bowen 2017). These models are student-centered and focus on students learning and understanding, while all their parts and stages are similar and overlap with each other, RCD incorporates both models stages within its framework, specifically the backward design process described in UbD not only because they both emphasize on the importance of setting clear outcomes for what learners will be able to do after instruction but also design authentic performance tasks based on the features represented by the acronym GRASPS (Goal, Role, Audience, Situation, Product or Performance and Standards) also known as McTighe-Brown GRASPS acronym (Wiggins & Mc Tighe 1998; Ainsworth & Donovan 2019). In addition, it is a more comprehensive, detailed hands-on model that serves as a road map and high-quality delivery system for the teacher to ensure students' success in state and national assessments for any subject whether English, Math, or Science. In addition, it provides vertical articulation, breaks down the designing parts into manageable chunks, builds on theories of conceptual understanding, and views assessment and learning experiences as closely intertwined in comparison to any other model. Finally, RCD is a framework model designed and set by practitioners for teachers, school leaders, and curriculum developers. Furthermore, Eckersall (2017) studied how implementing RCD units will affect students' achievement in three junior high schools in Southern California. His study followed a mixed-method approach, where it revealed an increase in students' achievement in high stakes tests by acquiring 21st century skills when implementing an RCD unit planning organizer that aligns the three core elements of a curriculum. Moreover, looking over curriculum development in the UAE, Ridge, Kippels, and Farah (2017) showed the history, the factors, and the challenges that influenced curriculum development and implementation in UAE. Their study showed how important it is to provide

an appropriate curriculum in public and private schools in terms of preparing future and skillful pioneers. The curriculum should be based on a comprehensive pedagogical approach and should be conceptualized holistically in terms of not only what needs to be taught but how it is delivered and assessed. To bring meaningful changes to the educational system in UAE, several suggestions were proposed starting with teacher training, expanding the scope of curriculum content and skills, effective evaluative strategies, and long-term capacity to develop curriculum investigation (Ridge, Kippels & Farah 2017).

2.4.1.2 Curriculum Design Components

Beginning with the end goal in mind has always been communicated to teachers (Covey 1991) however, how to allow and help the students to achieve the end goal was never properly elucidated or emphasized (Eckersall 2017). Promoting students' knowledge and abilities requires deliberate planning from teachers whereby their involvement in designing curriculum units of study requires them to reflect thoroughly on their practices. The units of study also known as unit of inquiry designed by teachers were based on clear learning outcomes, big ideas, and essential questions (Thomas 2000; Krajcik & Shin 2014; Larmer, Mergendoller & Boss 2015; Ainsworth & Donovan 2019), performance tasks, level of learning based on the priority and supporting standards and reflection (Oliva 2005; Wiggins & McTighe 2005; Tyler 2013; Ainsworth & Donovan 2019). Developing a mapped and well-aligned learning path when designing units relies on learning experience, instructions, and performance tasks (Ayala et al. 2008; Krajcik, McNeill & Reiser 2008; Ainsworth & Donovan 2019). Students' performance levels increase when instructions are based on real-world context, active learning, demonstration, writing, and high-order thinking skills (Marzano 2007). Therefore, the learning experience should be steered by students to promote the essential questions that require them to deepen their understanding and comprehension of concepts, problems, and issues which lead to a better understanding of the big ideas (McTighe & Wiggins 2013; Condliffe et al. 2017) and prepare them for the assessment (Childre, Sands & Pope 2009; Yokom 2020).

Meeting the unit of study learning outcomes and big ideas relies on the active mode of learning a curriculum is based on. Adopting performance tasks that are authentic and relevant, which are interdisciplinary by nature, equips students with the needed life-long learning skills (National Research Council 2012b; Eckersall 2017). In addition, these tasks provide learners with the opportunity to be involved in a project-based learning approach a powerful tool that is

absent in most traditional curricula (Ainsworth & Donovan 2019). Lastly, reflection is an integral component of a curriculum that evaluates the effectiveness of the unit as well as helps in refining the activities to meet the students' needs (Ayala et al. 2008; Ainsworth 2010).

2.4.2 Project-Based Learning in K-12 Educational Settings: Inclusion, Impact, and Assessment

PBL is a student-centered learning approach that deals with how rather than what students are learning (Kramer et al. 2007), which enables them to reach a higher level of academic achievement. It is a pedagogical approach of teaching through which students engage in inquiry, discover problems and challenges in the world around them, and try to solve these problems by distributing responsibilities among group members, researching, sharing thoughts and ideas, reflections, and displaying final products all while using their knowledge and skills acquired (Ardi 2015; Aldabbus 2018). As learning revolves around performance-based assessments such as projects that combine two or more disciplines, the integration will be one aspect of this curriculum. This integration allows students to deepen and broaden their knowledge and skills related to group work, communication, design, construction, research, and investigation (Helmane & Briska 2017). While the NGSS has emphasized on the importance of meaningful connection across multiple science contexts, integrating projects, ways of thinking, and knowledge from a variety of science and engineering disciplines (NGSS Lead States 2013) through PBL curricula, will allow students to develop conceptual knowledge and deeper learning skills (Buck Institute for Education 2017; Helmane & Briska 2017; Holthuis et al. 2018). To address all main constructs of this major theme, five subthemes are discussed in detail:

- Delivering standards through project-based learning;
- Impact of project-based learning: review and analysis;
- MAP-PBL impact and importance;
- Project-Based learning and the International Baccalaureate;
- Project-based learning assessment and curriculum;
- Benefits of PBL in second and foreign language settings.

2.4.2.1 Delivering Standards through Project-Based Learning

The Next Generation Science Standards is a mechanism that enables a student to learn through practical applications that are adopted as per SEP. These practices allow the students to

investigate cases and then design solutions based on real-world problems. The inclusion of a PBL in NGSS has replaced the traditional and lengthy lists of tasks with focused ideas and issues that require attention and practice to solve it (Holthuis et al. 2018). The involvement and alignment of PBL with the NGSS turned out to be fruitful (Holthuis et al. 2018) and an exciting way to teach science (Kasilingam & Chinnavan 2014). Furthermore, PBL reinforced the SEP, one of the NGSS three dimensions which helped students navigate through the curriculum and gave them opportunities to ask questions, use mathematical and computational thinking, develop models, plan investigations, construct explanations and analyze results by obtaining, evaluating, and communicating information through engagement (Weingarten, Ricker & Johnson 2020). Hence, developing such skills should be incorporated into the curriculum as according to Bell (2010), PBL is not and should not be a supplementary activity that enhances learning, but rather a core component of the curriculum, that involves a science-based approach which leads to the development of abilities that are also required in general learning circumstances.

A traditional educational system that promoted a readymade educational level turned out to be a failure in comparison to the PBL approach (Bas 2011; Holthuis et al. 2018). Designing curriculum should be authentic, primary based on standards, and designed in a way to be taught through and by PBL (Aldabbus 2018), whereby students will be challenged through a project that enriches their minds while meeting the grade-level standards and performance expectations (Holland 2015). Research has shown that students who learned science via a curriculum that involved a PBL approach were more motivated, engaged, and knowledgeable than others as they were the ones who would inquire, and infer knowledge to reach towards a solution in case of any on-ground anomaly faced (Kwietniewski 2017; Rubrica 2018; Mahasneh & Alwan 2018; Chen & Yong-Cih 2019).

2.4.2.2 Impact of Project-based Learning: Review and Analysis

Project-based learning has been used widely across all grade bands as it helps learners in developing pivotal skills for their success in school, university, life, and the workforce. Throughout the literature, several research studies investigated the effectiveness of PBL (Thomas, 2000; Holm, 2011; Nassir, 2014; Redmond, 2014; Ergul and Kargin, 2014; Karaçalli and Korur, 2014; Ayaz and Söylemez, 2015; Khaliq, Alam and Mushtaq, 2015; Aidoo *et al.*, 2016; Condliffe *et al.*, 2016; Sahli, 2017; Kwietniewski, 2017; Mahasneh and Iwan, 2018;

Rubrica, 2018; Chen and Yong-Cih, 2019; Saavedra, Liu and Haderlein, 2021; Krajcik *et al.*, 2021) in deepening students transfer skills (problem-solving, analytical skills, critical thinking, communication, teamwork, and collaboration) in different subjects as well as increasing academic achievement, engagement, application and retention of knowledge. However, a limited number of studies have investigated its efficiency and impact once centralized into the curriculum on students achievements (Aldabbus 2018; Rubrica 2018; Yokom 2020) specifically in middle school science classes in the middle east. Therefore, to better understand the impact of PBL, this section has started by addressing the main strength of PBL compared to any traditional instructions followed by a review on the effectiveness and impact of such approach, types, and curriculum design in teaching and learning. Subsequently reaching to the challenges and issues that may arise from such implementation.

2.4.2.2.1 PBL Implementation and Review

Diving into the literature, two recent university studies, funded by Lucas education research have shown that learners in PBL advanced placement classrooms (Saavedra, Liu & Haderlein 2021) and in elementary science classrooms (Krajcik et al. 2021) outperformed their peers in traditional classes by a margin of 8 % for over 6000 learners in 144 diverse schools across the nation. In addition, it has been shown that PBL outperforms any pedagogical approach specifically traditional instructions (The National Academics of Sciences 2019; Krajcik et al. 2021; Saavedra, Liu & Haderlein 2021) due to five main reasons. First, students engage in authentic and meaningful learning experiences and projects that allow them to apply their knowledge, work through the thorny issue and iterate until they solve problems (Darling-Hammond, Flook, Cook-Harvey, et al. 2019). Secondly, ensuring Students' buy-in and engagement in a project that addresses the standards and meets the learning outcomes depends on the topic chosen, interest, and needs (Yokom 2020). Therefore, selecting projects based on problems found within the learners' local and global community gives them more reasons to focus on addressing these issues, increases their motivation, sense of responsibility, confidence (Karaçalli & Korur 2014) and allows them to translate their academic knowledge into meaningful outcomes (The National Academics of Sciences 2019). Thirdly, presenting the outcome of the project by showing their knowledge in several ways by either constructing a model, representing and illustrating complex diagrams to conducting investigation or presenting to an audience (experts) allows students to embrace their skills and expand and transfer the

application of knowledge beyond their classroom walls (The National Academics of Sciences 2019). Fourthly, working in groups allows students to share their different experiences and perspectives and collaborate as a team to address problems and execute the project on which PBL inherently relies on. Thus, students acquire emotional and social skills such as teamwork, communication, and conflict resolution (Darling-Hammond, Flook, Cook-Harvey, Channa Barron, et al. 2019). Lastly, according to Darling-Hammond, Flook, Cook-Harvey, Channa Barron, et al (2019) working as a team in PBL teaches the students how to embrace and respect each other's background experiences and perspectives which helps to create a culture of belonging that is not found or enhanced in any traditional classrooms' instructions.

Additionally, it has been shown that the implementation of PBL in the learning process can contribute to the development of knowledge, intellectual skills, and the formation of students' attitudes (Handrianto & Rahman 2018). While the traditional classroom offers numerous possibilities for learners to hide in plain sight and pretend to be engaged in the learning which is referred to as the implicit deal (Rollins 2017), I will leave you alone if you leave me alone, such hiding spaces are non-existent in a PBL active classroom environment that is dominated by student-centered tasks. PBL offers education that focuses on students and provides them with valuable characteristics such as enthusiasm in learning, encouragement, collaboration, creativity, competitiveness, and empathy. While heterogeneous group investigations in PBL projects promote social skills, collaboration, and teamwork (Paschalis 2017) selective students group work also allows students to exchange their thoughts, and share their skills and strengths with other colleagues thus leading to inner motivation enhancement (Koutrouba & Karageorgou 2013).

While most of the literature and reviews performed on PBL emphasized its effectiveness in K-12 settings (Rubrica 2018) no reviews were conducted in terms of the development of PBL curricula, its implementation/practices, or impact on students outcome specifically MAP, as limited research studies were conducted on these topics. Guo et al (2020) conducted empirical studies review on PBL in higher education with a focus on students' outcomes. They focused on four main categories in their review: affective, cognitive, and behavioral outcomes next to artifact performance. The review indicated that the most crucial factor that focuses on solving an authentic problem is the creation of artifacts that distinguishes PBL from any other student-centered pedagogical approach. While very few studies have proven the effect of PBL on

students' content knowledge, skills and motivation, limited studies have implemented research designs that allow studying the effect of PBL on students' learning outcomes, especially in external assessments. Therefore, experimental research should be done in the near future, as recommended by Guo et al (2020), to evaluate the benefit of PBL on students learning outcomes. Finally, the review done by the authors has highlighted the three types of instruments that were commonly used when grasping the perception of students, teachers, and school leaders and for which our study will be adopting to grasp the teachers' perceptions: questionnaires, interviews, and observations. In addition, a meta-synthesis study was performed by Chen and Yong-Cih (2019) who reviewed 30 articles on PBL and students' academic achievement in primary, secondary, and tertiary education and the factors that influenced such approaches. While all studies were carried out in Western and East Asian countries, the results revealed that PBL has enhanced students' academic achievement regardless of the group size or educational stage; however, the results are influenced by the subject, instructional time, school location, and technology support. Further research was recommended to study the effect of PBL assignments on students' performance in different countries as well as to study the effect of PBL on teachers' and students' affective outcomes (i.e. perceptions towards the benefits of such approach, experience, and challenges) and skills. Moreover, Kwietniewski (2017) performed a literature review on PBL mainly in the United States whereby he deduced that PBL is a very effective instructional approach that strengthens students' skills; especially problem solving and critical thinking, and prepares the students for the workforce. Through his literature review, Kwietniewski (2017)) concluded that PBL improves students' academic achievements, is flexible in terms that teachers can adapt projects to meet the needs of their students, and requires time to ensure proper planning and training for teachers. According to his review, the curriculum should be rewritten and re-designed in a way to accommodate the implementation of PBL as an instructional approach and assessment type. Based on this conclusion, Kwietniewski (2017) recommended future research on how a curriculum can be adapted and designed when adapting a project-based learning method and what are the most effective ways to implement such a curriculum. In addition, as teachers play an essential role in delivering such an approach, training and professional development are other areas that need to be studied. Furthermore, Sahli (2017) has shed light on the effectiveness of PBL instructions through adopting an explanatory sequential mixed method in an urban school district in northern California. He tried to prove

that PBL can be used as an instructional strategy that not only improves students' growth scores in MAP but also directs educators to fully implement Common Core State Standards (CCSS) which allows students to gain a deeper understanding and knowledge of the concepts taught. Moreover, since teachers play an imperative role in this process, Sahli (2017) made sure to examine their perception towards the PBL process and implementation. His finding revealed that PBL achieved higher average MAP growth scores in both math and reading while traditional textbook usability was favored by teachers. Finally, the researcher also managed to make recommendations for future studies to better understand teacher resistance to PBL and argued for the need for a longitudinal study to provide unique insights related to teachers' comfortability in delivering PBL over a certain period which might lead to greater effect.

Looking through the literature it has been noticed that some studies that investigated the effect of PBL on science achievement observed no impact on students' outcomes (Araz & Sungur 2007; Yalçın, Turgut & Büyükkasap 2009; Ayan 2012; Kizkapan & Bektas 2017)). For example, Ayan (2012) found that there was no significant difference between the achievement test post-test scores of experiment and control groups in the unit of light at a fifth-grade level. The same was observed in Kizkapan and Bektas's (2017) quasi-experimental research study whereby they investigated the effect of PBL on middle school seventh-grade students' achievement in a chemistry unit pre-posttest entitled structure and properties of matter. Convenience sampling was used to select the participants and an independent samples t-test was performed to analyze the data. However, no significant difference between the experimental and control groups' scores was observed. According to Kizkapan and Bektas (2017), this may have been caused by several factors: minimum instructional time allocated (only four weeks) while the minimum time to deliver a PBL unit is six weeks (Ainsworth & Donovan 2019), teachers' role, students and teachers unfamiliarity with the approach, topics delivered, and communication between group members. However, Yalçın, Turgut and Büyükkasap (2009) found that there was a significant difference between the electric unit post-test scores. Another study carried out by Khaliq, Alam, and Mushtaq (2015) investigated the effect of PBL in teaching science at an elementary level whereby one grade 8 class of federal governmental high schools was randomly selected to take part in this study. A pre-posttest design was used to evaluate the effectiveness of PBL on grade 8 academic achievement in an environmental topic. The results showed an increase in science academic achievement for the experimental group.

Khaliq, Alam, and Mushtaq (2015) highlighted that PBL was found to be an effective approach to teaching science as it stimulates students' inquisitiveness to explore and recommended this approach to be used in all science subjects. Similarly, Ergul and Kargin (2014) conducted a study in which they analyzed through a quasi-experimental method, the effect of PBL on grade 6 students' success in electricity in life unit in two elementary schools in Turkey. An electric in life achievement pre-posttest was administered in the first period of the academic year 2010-2011, and showed a statistically significant difference between the experimental (PBL method) and control group (ministry of education programme) in terms of science achievement once the t-test was performed. Their study revealed that PBL increased students' achievement when comparing pre-test and post-test results between experimental and control groups. Two major suggestions are derived from their study; the first is related to the incorporation and implementation of PBL into the curriculum when designing units by teachers, especially in science. The second suggestion is related to the development of the teaching and learning process, collaboration, and interaction between teachers as well as a selection of contextual real-life project topics for students. Additionally, a study conducted by Redmond (2014) reported that PBL increased grade 4 academic achievement in MAP testing through active learning, collaboration, and meaningful project. The researcher used a variety of tools to solidify her data such as pre-posttest in MAP, a survey that measures students' motivation levels, interviews, journals, and Class Dojo, a computer application that helped determine students' attitudes regarding the approach used. Redmond (2014) highlighted the importance of teacher involvement in planning and implementing PBL in the classroom. This, in turn, makes the elements of PBL such as collaboration, teamwork, and research become first-nature to students.

Finally, reviewing and analyzing several research studies on PBL and their effectiveness in teaching and learning from the public, private and charter schools mainly in all grades at the high school level in several subjects, published between 2000-2010, Holm (2011) showcased how PBL is the key to shifting education towards student-centered methods and curriculum that is based on hands-on inquiry and active learning whereby teachers' involvement and guidance are imperative. His study revealed that PBL methods resulted in a greater impact on academic achievement and improved students' engagement compared to the traditional method. Moreover, the students highlighted that not only has this approach increased their engagement

and interest in the subject under study but also increased their understanding and content knowledge towards the subject.

Looking over the varieties of literature and meta-synthesis studies performed on project-based learning implementations and reviews whereby all research has highlighted the effectiveness of such an approach in K-12 educational settings, a classic and contextual gap exists in the literature. The classic gap in the literature highlights that the current study investigates a topic that has not been studied much in literature such as the rigorous curriculum design model that has been implemented for decades in the United States. However, a limited number of studies examined its effectiveness, usage, and implementation on students' achievement and skills whether in the United States or other countries and regions (Ainsworth 2011; Eckersall 2017; Sahli 2017; Ainsworth & Donovan 2019). Additionally, looking over the effectiveness of centralizing PBL in a curriculum and investigating its' effectiveness on students' achievement in external assessments specifically MAP testing has been advocated to be a strong future recommendation emphasized by several studies (Ergul & Kargin 2014; Condliffe et al. 2016; Kwietniewski 2017; Yin, Huang & Chen 2019; Guo et al. 2020; Yokom 2020). In addition, while there is a decent body of existing research on PBL endorsement, implementation, and effectiveness on students' knowledge, skills, engagement, and outcomes, most of this research was conducted mainly in North America, Europe, and Western and East Asian countries (Nassir 2014; Redmond 2014; Aidoo et al. 2016; Condliffe et al. 2016; Eckersall 2017; Kwietniewski 2017; Sahli 2017; Rubrica 2018; Yin, Huang & Chen 2019; Saavedra, Liu & Haderlein 2021) rather than in the MENA regions. Such a limited number of research in terms of centralizing PBL in a curriculum and investigating its' impact and effect in the Middle East region specifically on Emirati private school students highlights a contextual gap mainly on a specific population and geographic area that need to be addressed. Therefore, the current study that "Investigate the effectiveness and teachers' perceptions of rigorous curriculum design for project-based learning implementation on middle school science students' achievement and MAP scores in a private school in Abu Dhabi, UAE" will fill in the gap and add to the body of literature. As well as it will serve as a strong foundation for other researchers, policymakers, and curriculum developers to refer to and build on a cohesive, comprehensive curriculum that meets the cultural, contextual, and needs of UAE students. In addition, this study will benefit and serve as a precursor not only by helping in meeting the UAE national Agenda

2071 but for increasing students' MAP scores to meeting the international norms students thus substantially increasing TIMSS and PISA results for MENA regions countries.

2.4.2.2.2 PBL Implementation Challenges

Several factors interfere with the proper implementation of PBL in the learning process such as the student, the teacher, parents, the curriculum, the assessment type, and workshop. All these factors require proper equipment and resources, as well as information and communication technology facilities. While Jenkins (2017) claims that the efficacy of learning is influenced by three elements, one of which is the type of peer-to-peer interactions. There will undoubtedly be barriers and challenges in implementing the project to get the best marks or quality items. Similarly, when it comes to the influence on the participating students, there can be a wide range of opinions among educators about their outcomes in the learning process that adopts PBL, which sometimes can raise issues. Among the issues that face teachers with PBL implementation is the lack of collaboration time with other colleagues. Yaman (2014) found that the time allocated to interact with colleagues and peers was insufficient due to the limited meeting time and the intense curriculum content of the Basic Design set. Similarly, Petersen and Nassaji (2016) found that teachers do not have enough time to complete the syllabus because the skills measured were too broad and when the number of pupils sometimes exceeded 30 in a classroom this makes practical learning and hands-on activities very hard and sometimes impossible to be done perfectly thus, the PBL will be rarely properly applied. Another hindering challenge is related to the curriculum as it might not be designed to be taught by PBL thus teachers strive to find out how the content of the lesson could be modified and contextualized so it can be taught through PBL while preserving the learning objectives that derive from the standards (Aldabbus 2018). A major challenge to implement PBL in high schools is related to instructional time. This is due to the fact that students have an hour that is not embedded in their timetable, which forces teachers to focus on specific topics and content that only prepare and ensure student success on exams, making integration difficult (Quint & Condliffe 2018). Moreover, some teachers believe that PBL often takes more time than other methods of teaching which may delay the processes of presenting and covering the concepts required (Aldabbus 2018). Moreover, one major obstacle that affected PBL implementation is teacher confidence towards the delivery of such an approach as most of them believe that this approach creates lots

of noise in the classroom leading to yet another challenge related to classroom management (Aldabbus 2018; Handrianto & Rahman 2018).

Furthermore, the attitude of the students during the implementation of PBL could be an issue. In a project implementation study in the design course, Han, Capraro, and Capraro (2015) found that students failed to generate new ideas that could resolve the problem being studied. In addition, workshops, training equipment, and resource availability are important aspects that influence the implementation, of PBL in technical and vocational subjects (Handrianto & Rahman 2018). Finally, parents' involvement and collaboration may help greatly in the success of the educational process. An informative session with effective communication should take place between teacher-school-parents to prevent some parents from either doing the projects for their children or being unsupportive and negligent towards their children's needs (Aldabbus 2018). Hence, all these factors reflected in the conceptual framework were taken into consideration and accounted for in this study.

2.4.2.2.3 K-12 PBL Approach Types and Impact

K-12 students are exposed to PBL in a variety of ways: teachers or schools have access to an externally developed PBL curriculum known as a readymade curriculum; teachers can develop their own PBL approach. Alternatively, PBL can be part of the school's overall reform efforts or an important part of the school structure. In the latest years, several professional development organizations were mounted to assist and help educators, faculties, schools, and their systems in enhancing PBL usage and implementation in the classrooms. Three PBL approaches were described:

A. Externally Developed PBL Curricula

Providing teachers with externally ready-made developed curricula or curriculum units is one way to embed PBL into the classroom. Most of the research studies that investigated the effect of ready-made PBL curricula units on students' achievement were conducted mainly in the United States such as Investigating and Questioning our World through Science and Technology (IQWST) a middle school physics and chemistry curriculum (Shwartz et al. 2008), LeTUS curriculum materials that encompass five PBL science units built from the state, district and national standards to support science understanding in middle school (Rivet & Krajcik 2004) or the foundation of science curriculum framework based on PBL approach that is built around a real-life problem or question, development of products or artifacts, engagement,

collaboration, and usage of cognitive tools (Schneider et al. 2002). All these studies findings indicated an improvement across the science learning goals and inquiry process as well as higher pre-posttest scores. However, several limitations were highlighted from lack of a comparison group to non-randomization of samples, to finally lack of usage of standardized test scores. While little research has been done recently on the type of framework to be used to curricularize around PBL, Rubrica (2018) has studied the effect of PBL on the academic achievement of two Grade 6 sections, from Sta Quiteria Elementary School in Caloocan City, in science using Understanding by design framework. Each section was nominated as Gold (Group A) or Garnet (Group B) whereby the Gold was the experimental group and Garnet was the control group that was taught using traditional techniques. Pre-posttest was administered to both groups before and after the intervention whereby the results indicated a statistically significant difference in terms of students' achievement when taught using PBL curricula, in addition to positively influencing students' motivation and attitude towards science. However, Rubrica (2018) recommends that future studies focus on training and grasping in-service teachers' perspectives towards this approach and the importance of centralizing it into the curricula as well discover its effectiveness in other subjects. Mahasneh and Alwan (2018) have investigated, using a quasi-experimental pre-posttest design, the effectiveness of such an approach on student-teacher self-efficacy and achievement scores in Jordan whereby the results have shown a statistically significant difference between the experimental and the control group using a self-efficacy scale and achievement test. However, the researchers recommended more studies to be conducted in Arab countries to investigate and verify the effectiveness of PBL in teaching and learning.

B. Teacher-Initiated PBL Curricula

Supporting teachers to develop their own PBL approach whether through online available digital resources or through organizations that provide professional development services and initiatives such as: BIE, PBL institute, Edutopia, and much more, is of paramount importance. Some PBL design principles such as BIE's approach address the issues related to the content of a PBL curriculum (Thomas 2000; Darling-Hammond et al. 2008; Parker et al. 2013; Krajcik & Mun 2014; Larmer, Mergendoller & Boss 2015). The Gold standard PBL of BIE is grounded in its design elements on eight essential components that make a project design a Gold standard PBL one: challenging problem or question, sustained inquiry, authenticity, student voice and choice, reflection, critique and revision, and public product (Larmer,

Mergendoller & Boss 2015; Buck Institute for Education 2017) that aligns and overlap with the RCD framework as described in the study theoretical framework above. This model highlights the importance of focusing on teaching students content standards, concepts, and success skills (critical thinking, collaboration, and self-regulation) and allowing them to demonstrate them through authentic and meaningful projects. In addition, BIE offers teachers resources, project ideas, and rubrics relevant to their classrooms and is bound to its essential components to support and help teachers in designing or implementing PBL. Darling-Hammond et al. (2008) noted that inquiry-based approaches such as PBL projects or central problems should be designed to maximize students' exposure to big ideas embedded in the learning goals. Moreover, other research studies have stressed on the fact that the project, subject matter, or the content of a PBL approach should be authentic, meaningful, and affiliated to important issues in the real world (Thomas 2000; Parker et al. 2013).

C. PBL Part of Whole-School Approach

PBL classrooms stand out compared to any traditional teaching mode. While in some schools, teachers adopt PBL as an individual approach in their classrooms, others adopt such an approach as part of the whole school mission. Even though there are not enough data on the number of schools that have adopted PBL as part of a whole-school approach, its implementation, and alignment to high-profile education reform strategies and goals have been recently increasing (Condliffe et al. 2016). The American Institutes for Research aimed at helping students with their deeper learning. It has conducted a survey of schools participating in the Hewlett Foundation's Deeper Learning Network, which represents 10 school networks (more than 500 schools) whereby it has found that PBL was the most used educational approach across all participating schools in the study (Huberman et al., 2014). Examples of schools where PBL is enacted are: New Tech Network, Schools in High Tech High, Expeditionary Learning Schools, and Envision Schools. Looking into the ways for which the PBL approach can be integrated into K-12 educational classroom settings reveals that not all these approaches are explicitly linked to the PBL essential components and design exposed earlier in the literature. Therefore, adopting the RCD model as a framework to develop curriculum units centralized around PBL in our study would combine between teacher-initiated and PBL whole curriculum approach.

2.4.2.3 MAP-PBL Impact and Importance

Measures of Academic Progress also known as MAP tests are the most efficient benchmark tests generated by the Northwest Evaluation Association (NWEA). These untimed though supervised computerized adaptive tests are required to be done by all students enrolled in an American curriculum school at least twice in an academic year (Cordray et al. 2012). Some of these schools in the UAE implement it more than twice as these tests could be conducted up to four times in the same academic year to assess students' progress and academic growth in a specific period (NWEA 2012; Jones 2015). These tests measure and assess students' knowledge, skills, and understanding in Math, Reading, Language Usage, and Science. Once students complete their test, a detailed report data is generated by the NWEA system which gives the school and teachers, and parents an insight into each students knowledge level and what future concepts and skills they will be ready to learn (Cordray et al. 2012).

The MAP test is initiated by a variety of questions from a specific level that matches the level of the students. What makes MAP tests unique is the adaptivity feature. For instance, if a student failed to answer a question correctly, the computer will automatically adjust the difficulty and complexity of a question based on each student's level (Fiely 2015). Whatever questions are left will depend on students' performance levels in previous questions. As MAP is a computerized test, students' scores will be available as soon as the students complete the test. Scores are given as a Rash Unit (RIT), a vertical equal-interval scale that represents one of the IRT models (NWEA 2012; Jones 2015). Founded on the IRT theory, the RIT scale varies from one grade level to another and aligns and measures students' achievement levels with MAP test items with 31 difficulty levels on the same scale (Barber 2017). IRT can be used to analyze the process of learning related to MAP tests through three important elements, designing, scoring, and analyzing (Makransky et al. 2016). In addition, RIT can be classified as the ZPD when each learner reaches the point between the two levels knowing/not knowing when answering the questions in the wrong way (Barber 2017).

Currently, education sectors and schools are interested in implementing benchmark exams, specifically NWEA MAP for their own academic benefit. This is especially because MAP testing is a requirement for all American schools, as well as all schools in the UAE, as highlighted by ADEK. Throughout the literature, several researchers have reported MAP benefits such as its greatest impact on low and high-ability students (Cordray et al. 2012) due

to its three own features: grade independence, stability, and equal-interval scale (NWEA 2012; Medford 2014; Jones 2015). According to Fiely (2015), a significant difference exists between MAP tests and traditional standardized tests. MAP test information reveals individual strengths and weaknesses and identifies students' range of abilities on a learning continuum. This directs the teacher to determine the required skills needed for every learner (Johnson 2019). However, traditional standardized tests determine whether the learners have met specific educational standards (Barber 2017). In this current study, both assessments are taken into consideration to have a full overview of the effectiveness of the RCD-PBL.

According to NWEA (2016), MAP tests are beneficial to assess students in science as they are aligned with the NGSS. These tests give a clear idea on students' prior knowledge, and future academic needs, in order to prepare them for high school as well as allow school leaders, and teachers to evaluate the effectiveness of the implementation of a new curriculum, programme, or strategy on student's achievement and growth. Finally, evaluating the effectiveness of PBL on MAP scores has shown that PBL increases students' average MAP growth scores in math, reading (Sahli 2017), and science (Redmond 2014) through active learning, collaboration, and meaningful and authentic projects and assessments.

2.4.2.4 Project-Based Learning and the International Baccalaureate

The International Baccalaureate (IB) is a global leader in international education, where their programmes' mission relies on "developing inquiring, knowledgeable and caring young people" that enables students to take ownership of their learning and assist them in developing future-ready skills (IBO 2013, p.6). Three programs are offered by the IB: Primary Years Program (PYP) from age 6 to 11, followed by the Middle Years Program (MYP) from age 11 to 16 years old, and finally the Diploma Program (DP) for students aged 16 to 19 years old. While the MYP framework supports students to be critical, creative, and reflective thinkers, the MYP in science curriculum particularly relates science to daily life science applications through investigations (IBO 2013). In addition, such an educational programme supports the holistic development of middle school students whereby the Buck Institute of Education Gold standard PBL model helps teachers nurture students' growth. Additionally, PBL learning extends beyond the classroom to every student's home, community, and nation. As a result, students become active participants in their learning. Students can use the process to continuously reflect on their learning and improve their experiences. Since PBL maintains a balance for students to

understand and learn real-life skills that serve as the foundation for their preparation for any of the IB programmes and ties in with their mission (TNS Beaconhouse Defense 2018). Adopting PBL curriculum leads to a smoother transition from year 1 (grade 6) to year 5 (grade 10) and preparing them for the MYP personal project, cumulating project that happens at the end of year 5, from the beginning (Stock 2018). Learning through a projects-based curriculum not only helps them remember the information, but also teaches them how to apply it to unfamiliar situations, forming a lifelong habit of learning and acquiring important workplace skills. Thus, PBL fits in perfectly with the MYP framework (Stock 2018).

2.4.2.5 Project-Based Learning Assessment

PBL has its roots in the constructivist theories, whereby Thomas (2000) has highlighted the importance of students' involvement in constructing their knowledge in a PBL approach. Furthermore, Krajcik and Shin (2014), explicitly emphasized that the construction of knowledge can be examined by building a scientific product also referred to as an artifact. In addition, scaffolding the learning process is an integral component of PBL whether by the teachers, curriculum materials, peers, and technology, and it can guide students to complete complex tasks (Darling-Hammond et al. 2008; Krajcik & Shin 2014). According to literature, there is a gap and disconnection between the type of learning whereby it is based on PBL, the learning assessment, and teachers' accountability (Parker et al. 2013; Condliffe et al. 2016). A shift in education requires a reform in curriculum and a change in assessment type (Thomas 2000; Orpwood 2001; Parker et al. 2013; Whitaker 2019). While assessment plays an important role in the curriculum development process cycle (written, taught, and assessed curriculum) starting with the end in mind is the foundation of the backward design model on which the RCD is based. Therefore, identifying the assessment types and tasks is essential to evaluate students' knowledge and assess their skills. In addition, PBL requires suitable assessment practices to ensure that the learning process addresses all students. Embedding assessment throughout students' developed project, is based on three approaches (Condliffe *et al.*, 2016): Ensuring that a project is delivered to an authentic audience (Polman et al. 2014; Lenz et al. 2015), addressing its goals based on the standards assessed and its driven questions (Krajcik & Shin 2014) and providing continuous feedback and reflection (Darling-Hammond et al. 2008).

As the world around us is built upon multiple actions and interactions, ensuring effective integrated education as per Dewey's belief can be accomplished through the PBL approach

(Niedermeyer 2014) while delivering NGSS three-dimensional framework whereby its performance expectation is assessed through projects that integrate science, engineering practices and technology (Sahin 2019). Additionally, the basis of PBL is the development of projects (Yokom 2020) that require students to apply, demonstrate and reflect on their learning through performance and production-based tasks (Boss 2012; Yokom 2020).

While some PBL curricula allow students to set their driving questions to reinforce student choice, in this study, and as in Krajcik and Shin (2014) project-based science approach, the teacher and curriculum developer will be setting the questions and students will be given the freedom to explore different solutions based on their own questions set through the RCD-PBL curricula and in reference to the project they will be addressing in each unit. According to the definition of PBL by Tal, Krajcik, and Blumenfeld (2006), students will be involved in an authentic investigation driven by questions whereby students' engagement in this context increase due to their collaborative work with their peers as well as exchanging ideas, learning technology to find solutions, and building artifacts that demonstrate their understanding. Assessment plays an integral role in an inquiry-based approach like PBL (Darling-Hammond et al. 2008). The literature shows that there is a gap between the type of learning highlighted in PBL and the gaining of knowledge that will be assessed on standardized tests, which are frequently used as summative assessments for student-teacher accountability (Hertzog 2007; Parker et al. 2013). This perception creates frustration and anxiety among teachers and students. Identifying suitable summative assessments is intricate due to the fact that the PBL strategy is designed to produce some outcomes that a traditional summative assessment may not accurately measure (Hertzog 2007). A range of options has been discussed in the literature, most prominently performance-based assessments. This type of assessment requires students to complete tasks that showcase their capacity to apply the acquired knowledge and skills in meaningful learning tasks by responding to questions or solving problems they might have encountered in real life as opposed to selecting a correct answer type of questions generated from a multiple-choice test (Darling-Hammond & Adamson 2010). Similarly, Holm (2011) and Duke (2016) highlighted that these assessments require an extended period of time to allow students to investigate, plan and produce an artifact that addresses a real-world question or challenge. Therefore, adopting performance-based tasks that produce an artifact at the end of the unit surpasses any traditionally focused test in both

rigor and relevancy (Boss 2012). Shifting towards a student-based approach for assessment does not eliminate the traditional grading system, however, it changes the purpose of its assessment methods to a vehicle that reflects the progression of its learners towards the mastery of the NGSS and common core standards (Yokom 2020) throughout a semester rather than individual assignments cumulative points calculation (Shippy, Washer & Perrin 2013) as well as a tool for students feedback. By tackling the standards assessed and compensating all components of a project as defined earlier by Thomas (2000) performance-based tasks should increase students' academic achievement and interest in a subject (Fortus et al. 2005; Karaçalli & Korur 2014; Duke 2016), develop their science literacy competencies (Condliffe et al. 2017; Hairida & Junanto 2018) and ensure their readiness and success in their personal life and career (Buck Institute, 2018). Thus, adopting authentic performance-based tasks such as GRASPS will challenge students' attitudes towards STEM careers and allow them to use their knowledge and skills to solve real-world problems by producing an artifact (Barnes & Urbankowski 2014).

2.4.2.5.1 Project Types and Powerful Learning

PBL is a method that structures the curriculum around projects and leads to the creation or performance of a certain product. These projects reflect the learning process itself through authentic, inquiry-based activities whereby students demonstrate their knowledge and skills, share ideas, collaborate, and reflect on their thinking process and approach. While projects are classified into different types or categories, they differ in terms of the nature and sequencing of the project-related activities which the instructor and the learners decide on (Henry 1994). Three types of projects were recommended by Henry (1994): structured, semi-structured, and unstructured projects. Structured projects are prescribed and organized by teachers in terms of topic whereby the students have some choice in, resources, structure, methods of collecting and analyzing data, and presentation. Semi-structured projects are organized by both instructors and students. These projects prescribe the methodology and project area however, they require students to take more ownership and responsibility in the process. Unstructured projects are open-ended and entirely defined by students. Moreover, projects can also differ in the way sources of information are retrieved and data is collected. Also, they may differ in the way the information is represented in the end product. Stoller (2002) identified three categories that lead to different end-products: (a) production projects that entail written products, (b) performance projects that entail role-playing debates and oral presentations as products and (c) organizational

projects that require planning and leads to conversation table and clubs. Seif (2014) has elaborated on Stoller's (2002) projects categories and proposed seven types of projects that foster powerful learning and should be used more frequently throughout the K-12 curriculum:

- Reading/Writing Projects allow students to demonstrate their understanding, comprehension, and interpretation of text through books, plays, and poems reading either chosen by the students or assigned by the instructor. These projects often involve classroom discussions around the dilemmas and conflict identified in the reading materials, interpretative essays, stories, and poems assigned or chosen.
- Organizing projects allows students to collect, arrange and compile information and data on a certain topic, theme, or question from multiple resources such as reports, media, news, articles, and textbooks. Students might analyze interviews and surveys to explore essential questions and organize information into graphical displays such as graphs and charts. These projects also allow students to depict information that is usually symbolized in other formats such as music, artwork, and crafts.
- Investigation projects empower students to pose their questions around a topic as well as collect, organize, evaluate, analyze, draw conclusions, and share their findings through different formats whether in writing, oral presentations, audio and videotaping, artwork, photography, plays, models, or simulations. These projects are either based on students' own topic of research or focused on a specific academic topic that is being studied in the classroom. Scientific experiments are a sub-category of the investigation research projects. In these experiments, students plan their own investigations by setting their questions around a scientific problem, identifying variables, developing hypothesis, designing the experiment process to test their hypothesis, and collecting data that serves as the basis for evidence to answer scientific questions or test design solutions under a range of conditions and formulate results. While these projects are considered long-term activities, some can be conducted in short periods of time if adequate time is allocated to them.
- Design projects allow students to be creative and use concepts and principles taught to invent products, design technology, artwork, and models.

- Decision-making and problem-solving projects allow students to solve current and future complex problems and make decisions around a given situation that allows them to be involved in real-world issues.
- Argumentation projects allow students to write convincing essays, and papers that allow them to share and support their point of view, and reasons through evidence. Some of these projects are built around simulations and debates.
- Authentic, real-world projects lead to personal involvement. These projects allow students to take part in community service, understand and be part of the changing world issues and challenges. Through these projects, students cooperate and collaborate with each other, understand the current careers and their options in a multicultural real-world setting.

These seven research projects provide students with opportunities to master 21st century skills using powerful instructional pedagogical approaches that promote such projects. These projects are not completely discrete and may overlap. They can be done individually or collaboratively. For example, problem-solving and decision-making projects can be authentic and driven by real-world applications (Seif 2014).

2.4.2.5.2 Authentic Performance Tasks

A performance task is an assessment or learning activity that requires students to perform, and demonstrate their knowledge, understanding, and skills through tangible products or through performance that provides evidence of learning. In performance-based assessment, teaching and assessment are interwoven. Many written and standardized tests are based on Bloom's taxonomy which identifies higher-order thinking skills that learners use as knowledge and in their learning. Additionally, the performance-based assessment provides students with an opportunity to develop and demonstrate analysis, synthesis, and evaluation skills defined by Bloom's taxonomy. While assessment is the key to making positive changes in an educational programme, improving teachers' effectiveness, and enhancing instructions, current assessment types and practices must change (Lund & Kirk 2020). All those assessment, evaluation, and performance tasks are used for evaluative purposes to determine acceptable evidence such as performance tasks or projects, tests or quizzes, discussion, and informal observations as well as self-assessments (Wiggins & Mc Tighe 1998).

Performance tasks involve authentic tasks that are based on two dimensions: real-world application and students' interest and experiences that identify the knowledge, skills and demonstrate understanding through the GRASPS acronym. As per Wiggins and Mc Tighe (1998), the authenticity of a task is holistically represented through GRASPS as it results from the combination of the elements: (a) Application of learning, (b) meaningful context, (c) genuine purpose, (d) target audience, (e) realistic constraints, and (f) product/performance. Thus, the performance task requires and assesses one or more of these six facets of understanding (Iter 2017). GRASPS acronym stands for the steps in the process for which this design tool is used to develop performance tasks with an emphasis on context and whereby its acronym constitutes its success criteria (McTighe & Wiggins 2004):

- **Goal:** Defines the statement of the task by establishing the goal, problem, or challenges. It provides the students with the learning experience outcome, provides them with contextual purpose and product creation.
- **Role:** Defines the role for which the students will hold to accomplish the task. Most of the roles assigned to students in the performance tasks provide them with opportunities to complete real-life applications of content.
- **Audience:** Recognizes the target audience, a group of people that are interested in the performance task findings and products created by the student(s) assuming their role in the task and on which they will base their decision upon.
- **Situation:** Defines the context and scenario of the goal whereby the students will take on their role to perform the task.
- **Products/performance:** Clarifies what will be created and why by the students. The products or performances allow students to demonstrate their understanding and may vary based on their learning styles and abilities.
- **Standards:** Defines performance expectations and observable features evaluated through rubrics or success criteria.

The GRASPS design tool generates culminating products or performance-driven by performance criteria that offer a stem statement for which teachers can formulate a performance task (Mayes & Myers 2015). Such features embedded within the performance task provide relevant and meaningful learning targets and teaching goals with the evidence needed to judge and assess actual knowledge (Tomlinson & Tomlinson 2006). In this study, the performance

tasks are developed to show how a student uses and applies their scientific knowledge practically in a real-life situation rather than just providing information on a student's theoretical knowledge. Such a task rates students' learning process and assesses both product and process. These tasks provide a profile of a student's capabilities and allow them to appreciate their work processes and products. The usage of rubrics gives students an opportunity to self-assess, monitor, and reflect on their work and process (Iter 2017). To promote student-centered assessment, the below characteristics were highlighted in Fry, Ketteridge, and Marshall (2015) review of several assessment studies:

- Tasks should be challenging and require higher order thinking and learning, as well as learning from both other contexts such as college and work-based settings;
- Integration between assessment and learning whereby assessment should be part of the learning process;
- Assessment should promote metacognition and encourage thinking about the learning process as well as learning outcomes;
- Tasks should include the active involvement of students in finding things for themselves and developing the ability to learn independently;
- The task should be authentic, valuable, relevant, and give students some control over their work; and
- The task should be fit for purpose and is aligned to subject standards and performance expectations and learning outcomes.

2.4.2.6 Benefits of PBL in Second and Foreign Language Settings

For more than three decades, PBL has been advocated as an effective means for promoting language learning (Legutke & Thomas 1991; Stoller 2006; McPherron & Randolph 2013; Miller 2016; Kemaloglu & Sahin 2022). It has been recognized as an efficient instructional approach that allows the combination of language to content objectives, as language is indispensable to science (Victoria State Government 2021) since it improves research and literacy skills and engages students in meaningful real-world opportunities (Stoller & Myers 2019). The use of PBL in English Foreign Language (EFL) classes has been widely known to provide numerous benefits to students. The advantages of PBL have been outlined by researchers, and they vary from the improvement of language skills (Miller 2016; Pham 2018; Kemaloglu & Sahin 2022) to the enhancement of students' personal growth (Miller 2016; Pham

2018). Speaking, listening, reading, and writing are the four language skills that must be integrated into a project (Pham 2018; Kemaloglu & Sahin 2022) whereby students' grasp complicated scientific knowledge and processes are facilitated through knowing how to read and write scientific texts and graphs, for example (Yore, Bisanz & Hand 2003; Victoria State Government 2021). Therefore, literacy expectations for science extend beyond inquiry skills. Students can access new scientific content via reading, viewing, writing, speaking, researching, and listening to a variety of texts in science. As a result, their scientific understanding grows.

Moreover, teachers' anecdotal stories of successfully incorporating project work into their language classrooms with young, teenage, and adult learners, along with classrooms with general, vocational, academic, and specific language goals, have fueled most of the support for project-based learning. These anecdotes, combined with a small number of controlled research, show that project-based learning has significant benefits for second language and foreign language learners. An increase in language skills, enriched content learning, mastery of real-world skills, sustained engagement and motivation, and affirmative self-concepts are only a few of the benefits (Stoller & Myers 2019). Similarly, Levine (2004) claims that enhanced language abilities are the most widely recognized benefit of introducing projects in the foreign language classroom. Students have the opportunity to utilize language in a relatively natural situation (Haines 1989; Miller 2016) and participate in meaningful tasks that involve practical language use because they engage in intentional communication to complete realistic activities. This was also pinpointed by Miller (2016) who highlighted that these types of projects promote social interaction through meaningful and relevant activities that requires students, including EFL, to reach high level of rigor and apply not only their knowledge and skills but language whether through presentation, brochure, or others. Furthermore, as PBL is linked to standards and learning outcomes, specific academic vocabulary, syntax, language structure and function are used to develop rubric that assesses students final product (Miller 2016; Holthuis et al. 2018). All these favorable outcomes attest to project-based learning's perceived and proven benefits.

Teacher guidance, feedback, student participation, and elaborated assignments with some degree of challenge are all required in projects that are planned to maximize language, content, and skill acquisition. According to numerous case studies (Lee 2002; Gu 2004; Levine 2004; Allen 2008; Miller 2016; Artini, Ratminingsih & Padmadewi 2018), successful project-based learning:

- Emphasizes on integrated-skills and end-product reflection as it is a process and product-oriented by nature;
- Focuses on subjects that relate to the real world and sustain students' interest;
- Requires collaboration among group members while also allowing some degree of autonomy and independency among students; and
- Accommodates an explicit and purposeful focus on forms of languages and their aspects.

The end product result is due to authenticity of experience, improvement in content knowledge and language skills, development of metacognitive skills, improvement in critical thinking, decision-making and social skills, intensity of motivation and engagement along with familiarity with target language resources.

2.4.3 Teachers' Empowerment and Involvement towards Project-Based Learning Curriculum and Implementation

Designing a high-quality student-centered PBL curriculum based on RCD provides a coherent, cumulative, and well-sequenced enriched curriculum that deepens and broadens with each grade level (Ainsworth 2010; Ainsworth & Donovan 2019; Pondiscio 2020). However, this is only one piece of the puzzle. According to the National Institute for Excellence in Teaching (2020), having a high-quality curriculum that impacts students' outcomes relies on the successful implementation and member involvement (school leaders and educators) in designing, delivering, and supporting the curriculum. Therefore, teachers' being part of the designing process of a curriculum and understanding how the fundamental elements of this curriculum are aligned is pivotal.

Being key factors and part of the environment that affects curriculum implementation (Alsubaie 2016), teachers impact students' outcomes besides instructional timing, subject, location, and technology support (Chen and Yong-Cih, 2019), as they are the main points of contact with the students in terms of catering to their needs and delivering the instruction and curriculum programmes successfully (Hattie 2012; Sahli 2017). In addition, teachers empower and enhance the design process based on their knowledge, feedback, practical experiences

(Abudu & Mensah 2016; Konokman et al. 2017), and the needs of their students based on their context (Alsubaie 2016). However, teaching science through PBL requires teachers to abandon their standard teaching methods and develop a new perspective on teaching and learning (Mentzer, Czerniak & Brooks 2017). Teachers' understanding of PBL has an impact on how they plan and implement it (Tamim & Grant 2013) as the quality and outcome of students' learning depend on it (Erdogan et al. 2016). Furthermore, reflecting on such curriculum contributes to its successful implementation as teachers are key mediators between standards and outcomes (Sanders, Wright & Horn 1997; Konokman et al. 2017). Although teachers' key responsibility lies in the implementation of a curriculum to meet students' needs, their involvement, voice, and roles are important in creating and designing lesson plans and assessments within a framework of a given curriculum and can lead to its successful and meaningful development and implementation process (Carl 2009b; Abudu & Mensah 2016; Alsubaie 2016; Konokman et al. 2017).

While Several studies have supported teacher empowerment and involvement in the curriculum development process (Carswell 1977; Ben-Peretz 1980; Klein 1985; Handler 2010; Luciano 2014; Capraro et al. 2016; Konokman et al. 2017), their participation (Varis 1988), role as curriculum developer and implementer and perceptions towards the efficacy of such approach and its success is limited and has not been studied too often in recent years (Habók & Nagy 2016; Konokman et al. 2017). For instance, Ben-Peretz (1980) was one of the researchers that suggested a curriculum development approach in which teachers had been given a dual role as, implementers, and developers, whereby their selection criteria were based on the subject knowledge and teaching portfolios success in previous years. Moreover, Handler (2010) and Luciano (2014) highlighted the need for teachers' involvement in building and designing high-quality curricula while collaboratively and cooperatively working with school leaders leading to an effective alignment among the curriculum's core elements. The degree of involvement in the curriculum design process and its successful implementation will vary based on the teacher's willingness and readiness to participate in this process.

Upskilling teachers through professional development (Handler 2010; Condliffe et al. 2017), as well as the type of system centralized or school-based (Abudu & Mensah 2016), is an important factor that contributes to the success of curriculum development and implementation especially PBL (Capraro et al. 2016). Looking over three diverse urban schools, it has been

noted that the school where math and science teachers have received PBL professional development over three years, had the highest registered achievement in math and science state tests compared to another school that had not taken the training or had not implemented the PBL practices and principles learned in the professional development with fidelity (Capraro et al. 2016). Furthermore, ensuring the rigor in the delivery of PBL curricula is associated with teacher involvement and collaboration in designing the curriculum along with the project within its units as explored by Edmunds et al. (2017) through teachers' logs, surveys, and classroom observations in ten STEM-oriented North Carolina High schools. He concluded that a higher perception of rigor is associated with higher levels of PBL implementation whereby rigor indicator includes students thinking, justifying and reflecting on a process, opportunities to synthesize, generalize, summarize, interpret and apply their knowledge and skills to new familiar and unfamiliar situations, all to which reflect on the type of appropriate assessment to be used in PBL curricula specifically performance-based assessment (Krajcik & Shin 2014). Also, it has been noted that the effectiveness and implementation of an instructional innovation like PBL in the curriculum focus on the change in teachers' pedagogical beliefs and practices (Thomas 2000; Ertmer 2005; Park Rogers et al. 2011; MacMath, Sivia & Britton 2017) next to their knowledge, competencies, experiences, and faith in their students' capabilities and potential in learning through this approach is integral for its success (Mentzer, Czerniak & Brooks 2017; Viro et al. 2020). Similarly, teachers' willingness to change their beliefs about their role in the classroom from director to facilitator of learning is one of the key implementations for student-centered pedagogical approaches such as PBL (Ertmer & Simons 2006).

Moreover, while recent studies have shown that teachers', whether male or female, have similar perceptions towards curriculum development efficiency and implementation (Konokman et al. 2017) others have highlighted that gender differences affect the efficiency in implementation and teachers' perceptions (Akdag & Walter 2005; Capri & Celikkaleli 2008) thus, affecting teachers' motivation and enthusiasm. In addition, it has been observed that seniority is not a variable that affects teachers' perception towards curriculum development and implementation competency. Although it has been observed that the higher the teaching experience is the higher the competency of the teacher perception in curriculum development and implementation, it has been shown that teachers with less experience have even more

knowledge on recent research on curriculum studies as they graduated from educational institutions recently. Therefore, giving teachers a dynamic role in curriculum development with proper training and professional development will influence their perceptions, equip them with the required competencies and skills, impact students' achievements, and lead to the success of PBL (Badri et al. 2016; Konokman et al. 2017).

2.4.4 Teachers' Perceptions towards Project-Based Learning

When some teachers hear of PBL, they feel that this educational approach is not adequately preparing students for college since they believe that academic learning is still predominantly lecture-based (Sahli 2017). In the last 10 to 15 years, many instructors have felt constrained in their curriculum and instruction choices due to the pressures of high-stakes testing and accountability. Testing pressures in many schools resulted in a return to traditional teacher-directed instruction; yet, in many situations, the teacher was more of a servant of the publisher's programme than a director of instruction (O'Donnell 2008). Some teachers follow the textbook-based curriculum with fidelity. This implies a lack of creativity, disrespect for experience, and concentration on one-size-fits-all instruction and multiple-choice exams. The latter are some of the reasons behind why teachers believed that PBL can cause a loss of classroom management and behavior, as well as pre-planned lessons (Campbell 2012; Sahli 2017).

Diving deeper into teachers' views and perceptions on PBL in science and mathematics classes, it has been shown that their practice, professional competencies, and implementation of PBL greatly affect the learning outcomes in these courses (Kingston 2018) specifically in integrated science classrooms (Haatainen & Aksela 2021). Teachers felt more satisfied with their teaching methods and results when using PBL (Finkelstein et al. 2011) specifically when it is centralized in their curriculum units (Sahli 2017). In addition, Whitaker (2019) explored four middle school teachers' perceptions towards PBL's impact implementation of a first-year PBL curriculum in a high-poverty school in South Carolina over a period of 10 weeks as a way to prepare students for state tests. Through the questionnaire, semi-structured interviews, and observation of three out of the four teachers, Whitaker (2019) showed that even though teachers had positive perceptions of PBL, its implementation was hindered by technical challenges which were beyond teachers' control such as school policies that were unfavorable to PBL, lack of common planning time, ongoing professional development and assessment expectations all

these referred to as technical challenges as well as adaptive challenges such as school leadership and teachers collaborative effort and support.

Despite the multiple advantages that PBL centered curriculum offers from active learning to an increase in skills, knowledge, motivation, collaboration, student-centered learning, and education versatility, teachers' perceptions vary from one country to another (Haatainen & Aksela 2021). While teachers' perceptions of the advantages of PBL are consistent with earlier research and studies' findings (Kingston 2018; Whitaker 2019; Viro et al. 2020) some teachers still perceive PBL negatively due to their unfamiliarity with this approach (Viro et al. 2020) and reported several challenges related to planning time, collaboration with colleagues, and facilitating PBL (Mentzer, Czerniak & Brooks 2017; Whitaker 2019). Furthermore, Habók & Nagy (2016) studied the in-service teachers' perception towards their roles, methods, success, and evaluation of PBL compared to traditional classroom instructions in primary and vocational secondary schools. Analyzing his data collected through a questionnaire, his research study has shown that teachers who perceived themselves as facilitators and considered transmission of values and motivation as a fundamental part of their work favored PBL while those who perceived themselves as educators favored the traditional methods. In their study, Habók and Nagy (2016) stressed on the importance of upskilling teachers to meet the needs of the students and such a pedagogical approach. Thus, reforming or designing a curriculum that centralizes around PBL requires substantial changes in teachers' thinking, understanding, and dispositions towards classrooms, roles, and assessment mainly in integrated science education (Han et al. 2015). Overcoming PBL facilitation in a curriculum, teachers require experience, a deeper understanding of the implementation approach (Mentzer, Czerniak & Brooks 2017; Viro et al. 2020) alongside their involvement and being key stakeholders in curriculum development and implementation as they play an important role in classroom instructional practice (Abudu & Mensah 2016).

Therefore, selecting a clear and detailed roadmap and framework that supports the school vision and teaching philosophy such as RCD that is aligned (Buck Institute for Education 2019b) and funded on PBL as core while empowering teachers' roles and involvement (Ainsworth & Donovan 2019) is critical. Therefore, grasping the teachers' perceptions towards their involvement in designing and implementing RCD for PBL is pivotal as it will ensure that

the planned curriculum achieved its intended purpose as well as provide additional insight towards their understanding of the process and its impact.

CHAPTER III: METHODOLOGY

3.1 Overview

For the purpose of covering several aspects related to the phenomena under investigation,

the current study used a mixed-method approach study as it is reliable, gives accurate results, and increases validity since both quantitative and qualitative methods are used. For such an approach, pragmatism is adopted as it allows for multiple methods, differing worldviews, and a variety of data collection methods and reviews.

This chapter consists of several main sections in order to cover the methodology of the study by using an informative description. These sections are divided as follows: the research approach, data collection plan which embeds the methods, site, context, population, and sampling techniques, in addition to the data collection tools, validity, reliability, and trustworthiness of the instruments used in the study. Additionally, a brief overview of the data analysis plan and the ethical issues that were taken into consideration are also covered and explained in this section.

3.2 Research Approach

Educational research can be defined as an application of scientific research that aims at collecting useful and meaningful data to investigate and solve a specific educational problem (Tuckman and Harper 2012). Such research studies emphasize on a wide range of tested materials, resulting in trustworthy outcomes. These findings can be trusted and shared with others to improve teaching and learning as well as planning and processing (Morrell & Carroll 2010). Therefore, the type of research study and its objectives are the most important factors in determining the best techniques and approaches that should be adopted as they direct the research study's pathway (Fraenkel, Wallen and Hyun 2015).

In this research, a mixed method approach, defined as a “research that involves the mixing of quantitative and qualitative methods or other paradigm characteristics” by Johnson and Christensen (2014, p. 488), was adopted to collect the data needed to address the main questions in this study and achieve its purpose. Adopting such an approach gave a complete picture of the topic tested with accurate answers to complex dilemmas (Lund 2012). According to Creswell (2014), every research continuum should be based on a mixed method approach as

it combines several features of quantitative and qualitative approaches which provides a valuable contribution to any research study. Moreover, Creswell (2014) illuminates that such quantitative and qualitative approaches represent the two ends of the research continuum as they are not considered opposites. Additionally, adopting and collecting both quantitative and qualitative data improved the study's findings and eliminated the limitations that arise from the collection of each form separately (Creswell 2014). The results of the quantitative stage gave direction to the qualitative method, whose results were used to refine and validate the quantitative findings to ensure triangulation (Fraenkel & Wallen 2015). Consequently, conducting one approach, either quantitative or qualitative, was not going to be efficient to address the present phenomenon under investigation (Investigating the effectiveness and teachers' perceptions of Rigorous Curriculum Design for project-based learning on science students' achievement and MAP scores). Hence, to overcome the weaknesses of using a single approach, a mixed-method approach was adopted. This type of approach has never restricted the researcher to specific paradigms; rather, it is regarded as an authentic approach for doing research in both social and human science (Creswell & Clark 2011). Such an approach linked the purpose of the study to its questions and procedures regardless of the paradigm adopted in the study (Morgan 2014). Moreover, looking back to the literature similar studies (Ergul & Kargin 2014; Khaliq, Alam & Mushtaq 2015; Kizkapan & Bektas 2017; Sahli 2017) had adopted the same approach to investigate the effectiveness of PBL on students results and achievement.

Combining the use of both qualitative and quantitative approaches has helped in achieving better profundity and breadth of understanding of the examined phenomena (Fraenkel, Wallen & Hyun 2012). In addition, it has increased the researcher's confidence in the study's results by providing more evidence than those synthesized from a single approach (Creswell & Clark 2011; Caruth 2013).

While the quantitative approach tends to explain phenomena by examining the relationship among variables and collecting numerical data that are measured and analyzed using statistical procedures, the qualitative approach is based on various understanding and methodological traditions that allow the researcher not only to conduct the study in a natural setting but also to analyze words and report informant details perspective (Creswell 1998). According to Merriam, (2009), Fraenkel, Wallen, and Hyun (2012), such an approach focuses

on the deep understanding of an individual experience of the research variables and its outcomes can be obtained by utilizing subjective sources such as transcripts through interviews, and/or document analysis. However, some researchers such as Fraenkel, Wallen, and Hyun (2015) considered that using solely one type of research method will not yield accurate results. They have indicated that due to the inevitable subjectivity, the qualitative approach cannot solely and comprehensively address and explore all the results. Furthermore, other researchers (Denscombe 2008; Reams & Twale 2008) have indicated that following one of the two research methods (either quantitative or qualitative) will increase bias and decrease the accuracy of the results. As a result, adopting a mixed-method approach leads to more in-depth investigations, resulting in a more comprehensive and inventive approach to research (Johnson & Onwuegbuzie 2004). In addition, it will assist in answering more in-depth inquiries that may have been overlooked (Creswell & Clark 2011) and gather more significant and reliable evidence that can be used for current and future studies (Creswell 2013). Thus ensuring the expansion of the validity and the reliability of the study's results (Creswell 2009).

For this reason, an explanatory sequential mixed method was employed in this study. The purpose of such a research method is to combine quantitative and qualitative techniques to provide a better understanding of the issue or research problem than either approach alone (Teddlie & Tashakkori 2003). This explanatory sequential strategy is a popular strategy for the mixed method that often appeals with strong quantitative learning to the researcher (Creswell 2013). It is normally used to interpret and explain the quantitative findings through collecting and analyzing the qualitative data (Creswell 2013) as such data enriches and improves the outcome gained from the quantitative method and strengthens the results of the research study (Stange & Gotler 2006; Fraenkel, Wallen & Hyun 2015). Therefore, the study adopted such an approach as quantitative data provides a generalized picture of the core study problem only, whereas qualitative data delves into more details, which is useful in explaining the posited general picture.

In summary, the mixed method is a procedure for gathering, analyzing, and integrating or mixing both quantitative and qualitative data in the research process within a single study (Teddlie & Tashakkori 2003; Creswell 2014b) as neither quantitative nor qualitative approaches are sufficient to fully capture the trends and specifics of a situation. However, when combined, quantitative and qualitative methodologies strengthen one another and provide a more thorough

examination by utilizing the advantages of each other. While over 40 mixed-methods study designs have been published in the literature (Teddle & Tashakkori 2003), Creswell et al. (2003) have highlighted the six most often utilized ones for which the weight of each approach along with the data collection, analysis process, and stages varies within a mixed-method design. These include three concurrent and three sequential designs. Since the study's conceptual and construct components as well as the nature of the different research questions best fit the conceptual elements from both quantitative and qualitative designs, a mixed-method design has been selected. Moreover, looking at the order and type of the research questions adopted in this study, an explanatory sequential mixed method is chosen since greater attention and weight is given to the quantitative approach that it occurs first in the sequence and frequently comprises the main component of the mixed-methods data collecting process followed by the smaller qualitative component in the second phase of the research (Creswell et al. 2003; Ivankova, Creswell & Stick 2006; Creswell 2013) to refine, explain and elaborate on the results obtained from the quantitative phase by exploring participants' views (middle school teachers) in more depth. Therefore, the purpose of this mixed-methods explanatory sequential study was to investigate the effectiveness of the RCD-PBL implementation on middle school students' achievement and MAP scores in a private school in Abu Dhabi, UAE followed by grasping the perceptions of six purposefully selected middle school science teachers towards the development and implementation process of the RCD-PBL and its effectiveness on external assessments as teachers are key mediators and main stakeholders for successful implementation of a curriculum.

The Figure 4 illustrates the explanatory sequential mixed method research approach stages of this thesis that connects between quantitative and qualitative data and indicates how each will be collected; this shows how the data and analysis of the first method are used to build on and gain results of the second one. Each stage of this design has different tools and instruments however, all these tools and instruments complement each other to fulfill the outcome of the study. It took approximately ten months to collect and analyze its quantitative data especially because MAP tests were conducted in the Fall of 2021 and in the Spring of 2022. In addition, it took some time to develop and collect the interview questions that were based on the framework and data of this study. As for the qualitative data, it took around an additional month to collect and analyze the results.

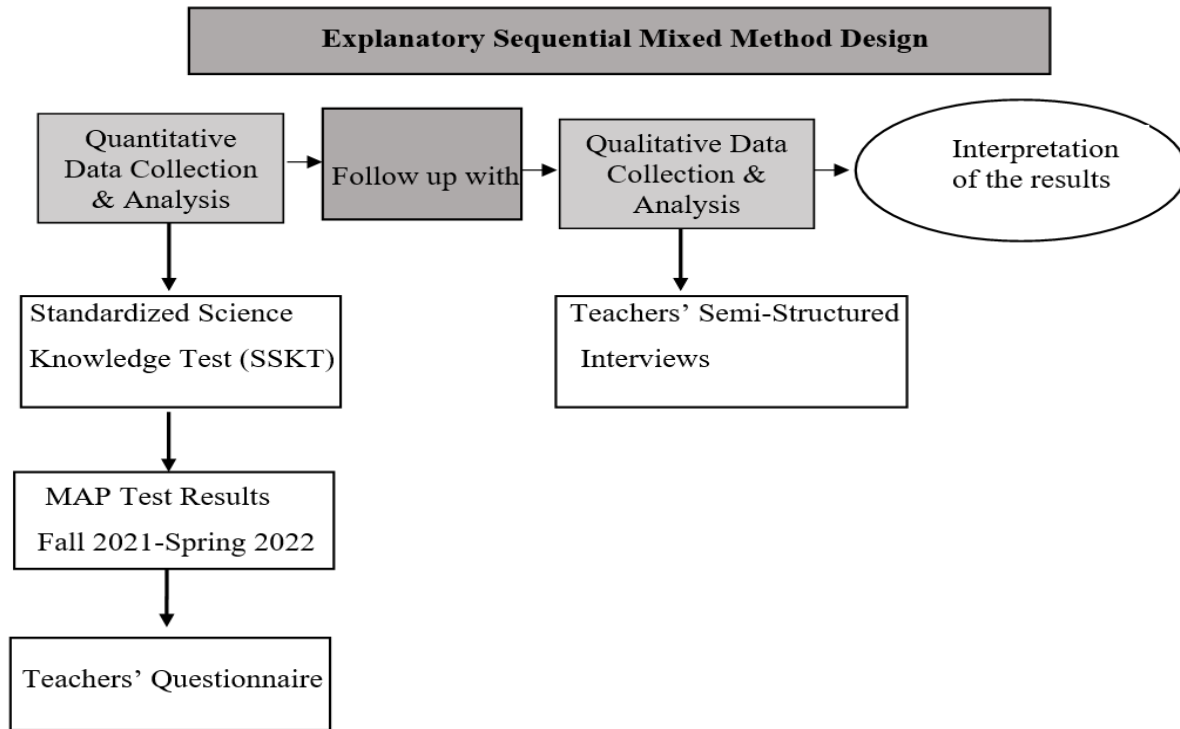


Figure 4: Current Study Research Approach Stages

Further, this study is conducted within a specific geographical and institutional boundary (a private school in Abu Dhabi, UAE) to investigate the relationship between RCD for project-based learning and students' achievements. Although it is bounded by a specific geographical locations or parameters, it can allow for a solid evaluation of the effectiveness of a program, intervention, or teaching method (Dawidowicz 2011). Adopting both quantitative and qualitative data helped explain both the process and outcome of the phenomenon investigated thus allowing the researcher to look beyond the quantitative results and understand the behavioral conditions from the teachers' perspective.

This research study followed a pragmatic paradigm “as a philosophical underpinning for mixed methods studies”, where “individual researchers have a freedom of choice” in the way they adopt their “methods, techniques, and procedures” to meet the purpose and the needs of their study (Creswell 2009, p.11). Emerging in the 1950s, this paradigm believed that “the world is changed through reason and action and there is an inseparable link between human knowing

and human action” (Goldkuhl 2012, p.7). It utilized the method that “appears best suited to the research problem without getting caught up in philosophical debates about which is the best approach” (Shirish 2013, p.68). Furthermore, pragmatists accept ideas that are validated through practice by processing and analyzing various data (Creswell 2009), they believe that there are several views and interpretations of research whereby several predictions may exist (Saunders, Thornhill & Lewis 2012). According to Khun (1970), a paradigm is defined “as an accepted model or pattern, as an organizing structure, a deeper philosophical position relating to the nature of social categories and social structures” (p. 23). While there is a direct relationship between the research and the use of paradigm, pragmatism attempts to use the most suitable research method to investigate a specific question, category, or theory (Feilzer 2010) as the nature of the study problem is the determining factor of a study methodology. Furthermore, as reality must be experienced as per pragmatist beliefs, this means students must interact with their environment to adapt and learn (Dewey 1998) whereby learning happens through hands-on tasks and approaches (Dewey 1916).

As a philosophical foundation for mixed methods research, scholars such as Patton (2002) and Morgan (2007) have highlighted its significance in social science research for concentrating on the research problem and then employing mixed approaches to reveal knowledge about the problem (Creswell 2009). Therefore, based on the research questions of this study, a mixed method approach has been chosen whereby both quantitative and qualitative data are required to be gathered as they help in answering the research questions thoroughly and give a better understanding of the analysis (Creswell 2013). Finally, adopting the pragmatist philosophy in this study is imperative as this philosophy focuses on the purpose rather than the process of the research (Dewey 1916, 1998; Creswell 2014a).

In summary, the pragmatism paradigm intends to find accurate and detailed knowledge related to the problem statement (effectiveness and teachers’ perceptions toward RCD for PBL implementation on students’ science achievement test and MAP scores), by assisting the researcher to collect the results of the study by adopting both quantitative and qualitative approaches (Rahi 2017) and to find a more prominent variety of perspectives. The mixed method approach presents better conclusions and reduces method bias that may result from utilizing either constructivism or positivism only (Subedi 2016). The current investigation needs to be accomplished in several ways to help in gathering adequate data that best address the

explanation and exploration issue, and explore its various angles (Creswell 2014a; Fraenkel, Wallen & Hyun 2015).

Finally, a quasi-experiment pretest-posttest non-equivalent control group design method was used to collect the quantitative data for this research study. This method is described as experimental whereby subjects are assigned to classes by the researcher in a non-random way as it is difficult to create artificial experimental groups (Creswell 2012). This type of research design is the most convenient when investigating the effect of an intervention such as the implementation of RCD project-based curriculum units in an educational setting (White & Sabarwal 2014).

3.3 Data collection plan

In the data collection plan, the researcher outlined the methods, site, context, population, and samples of the research study. A data collection plan assists in ensuring that data collected during the analysis is useful and collected appropriately.

3.3.1 Research methods

The research methods used for collecting data for the research study are illustrated in Table 1. Since a mixed methods approach is used, both quantitative and qualitative data were collected. The quantitative part of this study requires data collection from three types of sources, Standardized Science Knowledge test (SSKT), Measure of Academic Progress (MAP), and teachers' questionnaire, as mentioned in Table 1. To answer the first research question "To what extent does rigorous curriculum design for project-based learning implementation affect middle school students' achievement in science standardized knowledge test, in Abu Dhabi, UAE?", data was collected through unit 1 pre-posttest results generated from administering a standardized science knowledge test was based on each middle school grade level clustered standards. Each unit of inquiry is taught over the course of 6 to 8 weeks. The second part of the data was collected from students' MAP science scores tests results and document reports were analyzed and generated from the Northwest Evaluation Association (NWEA) server to address the second research question "To what extent does rigorous curriculum design for project-based learning implementation affects middle school science students' MAP scores in Abu Dhabi, UAE?" after getting the campus director's approval. The final source of data collection addressed the third research question "what are middle school teachers' perceptions towards rigorous curriculum design for project-based learning development and implementation in

science?”). The data collected to address the third research question came from an online survey that was shared with all teachers that were involved in designing and implementing the RCD project-based learning to increase collaboration and cooperation between campuses. Furthermore, the researcher visited classrooms whereby the intervention took place to monitor and ensure that the RCD-PBL curriculum is being implemented. Moreover, weekly departmental meetings were conducted to follow up on the implementation process, support teachers to overcome challenges and discuss, share ideas, students’ performance, engagement, and more as a team. In addition, the researcher was involved in setting up the MAP testing window schedules and invigilating the MAP tests to ensure triangulation and data validation. Finally, interviews were conducted with the middle school science teachers that have implemented the RCD for project-based learning where the research study is being implemented and evaluated to support and refine the quantitative findings.

Table 1: Research Design in Relation to Questions of the Study

The Purpose of the study	To investigate the effectiveness and teachers' perceptions of Rigorous Curriculum Design for project-based learning implementation on middle school science students' achievement and MAP scores in a private school in Abu Dhabi, UAE			
Approach	Mixed Method			
Design	Explanatory Sequential Design			
The Research Questions	Paradigm	Instruments	Data Analysis	Participants
Q1: To what extent does rigorous curriculum design for project-based learning implementation affect middle school students' achievement in science standardized knowledge tests, in Abu Dhabi, UAE?	Quantitative	Standardized Science Knowledge Test (SSKT)	Descriptive and Inferential Statistics	304 Middle School Students from grades 6,7, and 8.
Q2: To what extent does rigorous curriculum design for project-based learning implementation affect middle school science students' MAP scores in Abu Dhabi, UAE?	Quantitative	MAP Test Results	Descriptive and Inferential Statistics	295 Middle School Students with valid growth scores
Q3: What are middle school teachers' perceptions towards rigorous curriculum design for project-based learning development and implementation in science?	Quantitative	Structured Questionnaires	Descriptive and frequency analysis	25 Middle School Science Teachers
	Qualitative	Semi-Structured Interviews	Thematic analysis	Six Middle School Science Teachers

3.3.2 Study Site and Context

The current study is carried out in a private school with two campuses in the Emirates of Abu Dhabi from September 2021 through June 2022. The campuses chosen follow the American curriculum and the International Baccalaureate (IB) program which adopt the Next Generation Science Standards (NGSS). This school has been selected as it is one of the biggest schools in the United Arab Emirates with a student population of around 4000 students, most of whom are Emiratis, and with a reputable Abu Dhabi Department of Education and Knowledge

(ADEK) report. In addition, as the researcher is part of the academic admin staff, the site was accessible and the school was willing to take the initiative to design and implement a curriculum that serves students' best interest taking into consideration their mother tongue, is relevant to the context where the students live in and could improve their achievements in international exams. Furthermore, students' attainment is a focal point that ADEK focuses on when visiting schools for evaluation. In addition, and according to the Ministry of Education, all United Arab Emirates American private schools should conduct MAP tests at least twice a year from grade 3 to grade 9 (for Science) as specified by NWEA as part of their benchmark exams in order to track and measure students learning process, check their growth, compare their scores to international norms and evaluate the effectiveness of a curriculum or any educational approach. Therefore, the American Curriculum (based on the next-generation science standards and delivered through the IB framework) was an appropriate source of data for the current research investigation that assesses the effectiveness of RCD for PBL implementation on students' achievement and MAP scores in science. A sample of one RCD-PBL science unit for grade 8 (year 3 Middle Years Program) can be found in Appendix A. Moreover, one of the main goals and vision of the school is to achieve 2021, and 2071 vision targets and UAE National Agenda that concentrate on students ranking among the top in the world in reading, mathematics, and scientific tests as well as having a solid knowledge of the Arabic language. Additionally, the agenda aims to raise secondary school graduation rates to international levels and ensure that all schools have an outstanding leadership team and an internationally recognized teaching staff. Finally, one of the school's main targets is to increase the number of talented students with critical thinking and problem-solving skills which prepare them for future careers and the workforce.

3.3.3 Population and Sampling Technique

The major questions of the study are centered around middle school students' academic achievement and MAP scores as well as teachers' perceptions towards RCD-PBL units of study. Therefore, the main population of this study encompassed all middle school science teachers (N=25) that were trained over the past two years and were involved in the design and implementation of this model and had at least three years of teaching experience within the school to ensure that they had taught at least one year using the traditional textbook method to be able to compare the two instructional modes of delivering science. In addition, 955 middle

school students divided across grades 6 to 8 took part in this study. Each grade level is divided into sections whereby each classroom holds a maximum of 27 students. According to Krejcie and Morgan (1970) for a population of approximately 955 a sample size of 275 is acquired at least to guarantee the validity and reliability of the results whereby sampling is the process of selecting participants as defined by Fraenkel, Wallen, and Hyun (2015). In this private school, boys and girls are separated from grade 5. Therefore, to monitor and ensure proper implementation of RCD-PBL and not violate the bubble divisions done by the campus due to the COVID situation, 304 participants from 12 science classrooms took part in this study. From these 12 science classrooms, 6 classes followed the RCD-PBL curriculum modules (experimental group), while the 6 other classes adhered to the conventional textbook-based curriculum (control group). Finally, for each grade level, the sample contained two classes of males (experimental and control) and two classes of females (experimental and control) as represented in the Table 2.

Table 2: Middle School Sample Population

	Females		Males		Total # of Participants	Teachers GS	Teachers BS
	Exp	Cont	Exp	Cont	Exp/Cont	Exp/Cont	Exp/Cont
Grade 6	26	26	25	25	102	1	1
Grade 7	25	27	25	25	102	1	1
Grade 8	25	25	25	25	100	1	1
Total	76	78	75	75	304	3	3

- Exp = Experimental Group; Cont = Control Group

A quasi-experimental pre-posttest design with naturally occurring comparison groups was adopted to tackle the first two research questions related to students' achievement and MAP scores. The difference between experimental and control are expected to be related to different skills and learners' achievement levels (Fraenkel, Wallen & Hyun 2015). Convenient sampling was adopted as it is the best to test the implementation of RCD for a project-based learning curriculum (experimental group) compared to the textbook curriculum (control group). One experimental group and one control group with similar demographics, Pre-test results mean average, and similar mean and standard deviation deriving from their MAP scores Fall to Winter 2020-2021 were selected in each grade level. The same sampling technique was adopted to

address the quantitative part of data collection related to the third research question whereby, teachers' participation in the questionnaire was optional and anonymous. The link was shared with all teachers through the daily bulletin message sent by admin every morning with a clear purpose of targeting middle school teachers who were involved in the process to increase participation and honesty in response. This type of sampling method was convenient not only due to the pandemic situation, which made it difficult for teachers to take part in any activities, but also due to the accessibility of the researcher to the selected population of middle school students and science teachers (Fraenkel, Wallen & Hyun 2015).

In addition, purposive sampling was adopted for the qualitative part whereby six teachers were selected to deliver the new units from the total population of middle school science teachers and were interviewed to be able to analyze, explain and support the results of the quantitative findings. Given that this study focused mainly on middle school (Grades 6-8) and based on the timetables and schedules set by the school admin teachers teaching grades 6-8 are selected. Among these teachers, only returning staff with three years of teaching experience within the school were chosen to ensure that they had taught at least one year using the traditional textbook method to be able to compare the two instructional delivery models. This information was shared by the Human Resource team based on the campus director's approval and was later confirmed from the demographic section of the questionnaire. In addition, teachers with the highest number of teaching sections within this grade level were chosen. Further selection happened based on the microbubbles plan. Based on the Ministry of Education and health authority safety requirement, Girls' School (GS) and Boys' School (BS) teachers sharing the same microbubbles were selected. Therefore, N=6 teachers, three from GS and three from BS, who implemented the RCD-PBL in one of their classes and taught using the textbook in the others were selected as observed in Table 2. These six teachers were invited to take part in the interview via email. The email introduced the research, explained the purpose of this study, and asked for the interviewees' consent, recording permission and availability (date and time) for an interview.

3.3.4 Difference Between Traditional and Project-Based Learning Classrooms

The experimental group consist of classroom having PBL units being implemented whereby the emphasis tends to go from the teacher to the students. In these settings, the teacher assumes the function of a facilitator who encourages, guides, and supports students to deepen

and evaluate their understanding and knowledge, and hence, their learning. In addition, these classrooms differ from typical traditional classrooms (the control group) is that both teachers and students consider knowledge as a dynamic, constantly-evolving perspective rather than a set of disconnected facts to be memorized. While the course goals, objectives, and outcomes may be the same for both traditional and project-based learning classroom groups, the Table 3 below differentiates considerable variations in fundamental assumptions about teachers, knowledge, students, and learning.

Table 3: Differences between Traditional Instruction and PBL Classrooms

Project-Based Learning Classroom “Experimental Groups”	Traditional Classroom “Control Groups”
Curriculum emphasizes big concepts, beginning with the whole and expanding to include parts	Curriculum begins with the parts of the whole. Emphasizes basic skills
Group and collaborative learning	Individual learning
Student-centered: constructing individual knowledge	Teacher-centered: transmitting knowledge
Authentic learning in context	Learning out of a context
Pursuit of students questions, opinions, and interest is valued.	Strict adherence to fixed curriculum
Resources include primary sources of materials and simulations, hands-on practicals and experiments.	Resources are mainly based on textbooks, worksheets.
Scaffolding of learning to meet students’ needs	One size fits all instruction
Learning is interactive and builds on students’ prior knowledge and experience	Learning is based on repetition
The project is intertwined with the learning experience and drives the learning process throughout the weeks of instructions	The project is the end-unit assessment summative to evaluate students’ knowledge and usually allocated one or two blocks.
The project is authentic, meaningful, and relevant to the context of students and requires the creation of a tangible product that will be represented to an authentic audience	The project is delivered as found in textbooks adopted in the school. No presentation to an authentic audience.
Performance-based assessment based on GRASPS tasks whereby students take an active role in society to address and solve problems and challenges.	Traditional Assessment, no role taking, expectation priorly set and might not be related to their current context.
Product will vary based on students’ approach, voice, and choice taken to address the issue.	Fix sets of guided instructions with one required outcome or type of product.

3.3.5 Designing Rigorous and Relevant Curriculum Units of Study Process

There are many ways to implement the Next Generation Science Standards (NGSS). While a pre-made curriculum may be purchased by schools from an outside source, this sort of curriculum is developed by individuals who have never visited the Gulf Cooperation Council (GCC) nations or are not familiar with the needs or context of our Middle East and North Africa (MENA) area pupils in general. As a result, the school where the research was conducted intended to give the curriculum's ownership to those who knew their pupils the best. Therefore,

middle school science teachers' instructional leadership teams from grades 6 to 10 were formed for each grade level to create such PBL curriculum units that align the NGSS to the learning experiences and assessment. All middle school Science teachers involved were trained in the RCD, PBL, and NGSS (unpacking standards and developing performance tasks). Such a design was chosen as it provided a clear and systematic approach to creating such curriculum units. In addition, it attributes over cross and overlap with the Buck Institute of Education Gold standard PBL model whereby both have authentic projects at the core of their learning experiences as explained in detail in chapter 2.

Having Emiratis students at the center of the rigorous curriculum, and for the purpose of maximizing the learning from the RCD curriculum units, teachers kept in mind their students' needs, context, and interests when they were developing the units. Intensive professional development and designing process sessions were scheduled for two days per week whereby each session was set for 2.5 hours. The process was initiated by introducing the five main RCD steps below, by RCD leaders and curriculum experts, that helped build the foundation of the curriculum:

1. Prioritize the standards
2. Name the unit of study
3. Assign priority standards and supporting standards
4. Prepare a pacing calendar
5. Conduct the unit planning organizer

Based on these five fundamental steps, and since the school middle year cycle deliver NGSS through International Baccalaureate (IB) framework, RCD-PBL unit planners were based on IB Middle Year Program (MYP) requirements and connections as seen in stage 1 (inquiry) Figure 5 of the units built. This stage is filled out once priority standards are clustered, selected and unwrapped in order to set the PBL tasks that will be interlinked throughout the teaching and learning followed by stage 2 (action) which highlight the teaching and learning through inquiry. This section highlights and showcase the alignment between the content which embeds the priority and supporting standards, the learning targets unpacked from these standards along with the academic vocabulary and the skills that students will acquire. Finally, stage 3 (reflection) elucidates the reflections of all stakeholders involved prior to, during, and after teaching the units to make the changes and enhance the units moving forward. This stage is considered the

most important stage in any curriculum development process whereby all stakeholder units' feedback is compiled and reflected on by the initial group of teachers, leaders, and experts that were involved in each unit design process per grade level. Based on the feedback given, the required changes were made.

Teacher(s)	Subject group and discipline		
Unit title	MYP Year & Grade	Unit duration (hrs)	

STAGE 1: INQUIRY: Establishing Purpose of the Unit

Key concept	Related concept(s)	Global context & Exploration
Statement of inquiry		
Inquiry questions		
Factual— Conceptual— Debatable—		
Objectives	Summative assessments	
	Outline of summative assessment task(s) including assessment criteria:	Relationship between summative assessment task(s) and statement of inquiry:
Approaches to learning (ATL)		

STAGE 2: ACTION: Teaching and Learning through Inquiry

Content	Learning Experiences and Teaching Strategies	Formative Assessment	Differentiation	Resources
Block # Priority Standards Learning Targets Supporting Standards Academic Vocabulary ATL Skills	Launch and Inquire Explore Practice and Present Reflect and Connect		Which way will you differentiate? 1. Content 2. Process 3. Product 4. Learning Environment	
Resources: (Published) Always filter as per the cultural sensitivity guidelines.		Resources: (Teacher Created)		

STAGE 3: REFLECTION: considering the planning, process and impact of the inquiry

Prior to teaching the unit	During teaching	After teaching the unit

Figure 5: RCD-PBL Unit Planner Sample

In order to properly develop these units of inquiry, and to ensure proper connections and alignment between standards, instructions, and assessment, a detailed checklist process steps and primary tasks (Appendix B) was set by RCD curriculum experts, leaders for which the

researcher was part of and shared and explained to teachers. Each subject specific leader with the help and support of the school middle year program coordinator were overseeing and checking the work of teachers, providing constructive feedback, and working with them in parallel to understand the process and develop the units. The detailed rigorous designing process steps and tasks were divided into six parts by the RCD curriculum experts reflecting the stages and the building foundation steps highlighted by Larry Ainsworth's RCD roadmap design. These process steps parts were not only a roadmap for teachers to follow to ensure all key components are in place but also served as a checklist for RCD leaders, experts, and coordinators when reviewing the process to make sure that the design is according to the guiding principles of the RCD and PBL. These parts are defined as follows:

1. **Prioritize the learning targets** based on readiness, endurance, leverage, and external assessments of the standards adopted for the cycle.
2. **Unwrap the priority standards** allowed teachers to determine the concepts (what students need to know) and skills (what the students be able to do), assign success criteria to learning targets, and select academic vocabulary based on the performance expectation of the priority standards.
3. **Create a pacing calendar** that ensured horizontal and vertical articulation across the science curriculum as well as set proper timelines for the units developed.
4. **Create unit assessments (Pre/Post/dipsticks)** helped to evaluate and measure the prior and acquired knowledge during the implementation process and be able to reflect on and scaffold the learning for the students and evaluate the effectiveness of these units.
5. **Plan rigorous and relevant learning engagements** that motivated and empowered students to track and monitor the progress of priority learning targets. In addition, developing and centralizing PBL performance tasks (GRASPS) throughout the learning experience created opportunities for student agency and ensured global mindedness.
6. **Pre-Assess, analyze data, teach the unit, post-assess, analyze data** ensured proper data teams meeting to determine students' needs and decide how to differentiate instructions based on student assessment evidence.

Following the professional development sessions and looking closely to grade 8 as an example for re-designing the curriculum, four middle school science teachers have identified the priority standards with the help and support of the RCD experts and subject-specific leaders. Following

the roadmap checklist attached in the Appendix B, all disciplinary core ideas related to these power standards with their practices were identified in Table 4, unwrapped, and assigned to specific success criteria.

Table 4: Forces and Motion Unit NGSS Priority Standards

NGSS Practices Practice 1: Asking Questions and Defining Problems Practice 2: Developing and Using Models Practice 8: Obtaining, Evaluating, and Communicating Information
NGSS Disciplinary Core Ideas PS2.A: Forces and Motion: For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton’s third law). (MS-PS2-1) PS2.A: Forces and Motion: The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion. (MS-PS2-2) ETS1.A: Defining and Delimiting Engineering Problems: The more precisely a design task’s criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions. (MS-ETS1-1) ETS1.B: Developing Possible Solutions: Models of all kinds are important for testing solutions. (MS-ETS1-4)

Then from the practices, crosscutting concepts (Structure and Function), and content unwrapped from the standards, the IB framework components such as the key concepts, related concepts, global context, statement of inquiry, and inquiry questions (factual, conceptual, and debatable questions) were selected, developed, and reviewed by MYP and subject-specific coordinator, Table 5 before developing pre-posttests, the PBL performance task and success criteria.

Table 5: Grade 8 Stage 1 Unit planner Sample

STAGE 1: INQUIRY: Establishing Purpose of the Unit

Key concept	Related concept(s)	Global context & Exploration
Relationships : Relationships in sciences indicate the connections found among variables through observation or experimentation. These relationships also can be tested through experimentation. Scientists often search for the connections between form and function. Modelling is also used to represent relationships where factors such as scale, volume of data, or time make other methods impractical.	Function : A purpose, a role or a way of behaving that can be investigated; a mathematical relationship between variables. Movement : The act, process, or result of displacing from one location or position to another within a defined frame of reference.	Global Context: Scientific and technical innovation Exploration: process and solutions
Statement of inquiry		
CONCEPTUAL UNDERSTANDING: Relationships exist through functions and movements. STATEMENT OF Inquiry: Relationships between functions and movements can be used to design processes and solutions		
Inquiry questions		
Factual: What is movement? How is the objects movement related to force? What processes need to be considered when designing new solutions? Conceptual: What types of relationships are established through functions and movements? Debatable: Does every problem have an ideal solution? (Is there a perfect design?).		

Once the framework was checked, reviewed, and approved, teachers, started to brainstorm some ideas to develop the PBL performance task around which the learning experiences will be built around. In addition, the Science Standards Knowledge Test (SSKT) Pre-Post unit assessment was built based on the expected knowledge required based on the standards of a particular grade level. The standardized tests were built by the grade level teams reflecting all depth of knowledge (DOK) levels. The test was checked by the subject and K-12 coordinator as well as an expert in the field of the science curriculum. Moreover, the G.R.A.S.P.S. performance task by Jay McTighe and Grant Wiggins was used to construct the task scenario. Looking over the priority standards unwrapped targets, the performance task in Table 6 was developed coupled with the appropriate resources and simulation such as Futura engineering in Amplify to build and test their design. Furthermore, teachers referred to the seven elements of the Gold Standard PBL model to set contextual, student-centered, authentic, and relevant tasks that will require students to demonstrate their understanding and competencies

through a product or a performance. While other grade levels PBL projects varied from breeding the fastest camel in grade 6 to designing the fastest rollercoaster in grade 7.

Table 6: Grade 8 UAE Red Crescent Supply Pod GRASPS Task

GRASPS Performance Task: UAE Red Crescent Supply Pod
Goal- Design a solution using knowledge of forces and motion to minimize damage and waste when dropping supply pods. Role- You are a mechanical engineer working for UAE red crescent foundation. Audience- Your audience is the board of directors at UAE red crescent foundation. Situation- The UAE red crescent foundation is the UAE’s main relief and aid agency that provides relief during natural disasters. One way it does this is by using helicopters to drop emergency supplies in areas that have been affected by natural disasters like earthquakes or floods. The emergency supplies must be packed in containers called supply pods that protect the supplies as they hit the ground. The UAE red crescent foundation has issued a Request for Proposals (RFP) for the development of supply pods to hold emergency supplies as they’re delivered to people in need. Successful proposal designs will address the following three criteria: 1. Minimize cargo damage. 2. Maximize shell condition 3. Keep costs low In addition to meeting the above criteria, the design of the supply pod should take into account the constraints or limits to the possible solutions. These constraints include: • Supply pod must be delivered by helicopter. • Supply pod must be dropped from the same height for each test Product- Proposal form for finalized Supply pod design. Students’ choice to present the product whether through Oral, written, or visual forms. Standards- MS-PS2-1, MS-PS2-2, MS-ETS1-1, and MS-ETS1-4. This GRASPS task thoroughly summarizes the design request and describes the proposed design by listing the details of multiple design tests and the results. The process embeds multiple pieces of strong evidence to support the design decision, thoroughly explaining why the specific features were selected over other options and how that feature of the design relates to the success criteria. The description of design priorities should be clear; the summary of the optimal design should be detailed and thorough and includes a strong closing statement. IB Rubrics- Criteria Based Criterion A: Knowing and Understanding ii. Apply scientific knowledge and understanding to solve problems set in familiar and unfamiliar situations Criterion C: Processing and Evaluating i. present collected and transformed data ii. interpret data and describe results using scientific reasoning v. describe improvements or extensions to the method Criterion D: Reflecting on the impacts of science i. describe the ways in which science is applied and used to address a specific problem or issue ii. discuss and analyse the various implications of using science and its application in solving a specific problem or issue iii. apply scientific language effectively iv. document the work of others and sources of information used.

All these PBL performance tasks were built by referring them to the Gold standard PBL model for which the RCD framework centralizes around to make lessons grounded in standards, student-centered, relevant, and authentic to students, schools, as well as their larger community. Such a PBL model helped all stakeholders (teachers, admins, and schools) to develop and implement high-quality PBL by not only providing an appropriate amount of structure and guidance to set proper projects but allowing for flexibility and ease of use across all grade levels and subject areas. Furthermore, the seven essential project design elements of the PBL model: (1) challenging questions or problems, (2) sustained inquiry, (3) authenticity, (4) student voice and choice, (5) reflection, (6) critique and revision, and (7) public product, are aligned with the RCD project core attributes for which the learning experience is based on Table 7. Within these models, students learning goals for projects include standards-based content and 21st-century skills such as critical thinking, problem-solving, self-management, collaboration, and communication. These authentic projects founded by both models ensure student autonomy, accountability, authenticity, reflection, voice, and choice as they are mostly student-driven and related to real-life topics and problems. Thus, making the RCD a collection of PBL units.

Table 7: Cross-Walk and Alignment between Core Project G.R.A.S.P.S and Gold Standard PBL Model.

Gold Standard PBL Model criteria to measure the fidelity of any PBL project or lesson	G.R.A.S.P.S Authentic Assessment and Performance Tasks	Crosswalk and Alignment
Challenging Problems or Questions	Goal Audience Situation	Framing the project with a meaningful context and problem to solve.
Sustained Inquiry	Research stage	Symbiotic process component that drives students' learning objectives, which in turn propels the inquiry process. As students gain knowledge, the number of questions they must answer decreases, allowing them to move on to the PBL's subsequent stages and get ready for the public product.
Authenticity	Authenticity is applied to both the internal S-element of the GRASPS, which links the topic and task to curricular standards and benchmarks, and to each exterior aspect of the GRASP performance task design model.	Motivating and engaging students to learn in a meaningful context that relates to their everyday lives issues and speaks to their interests.
Student voice and choice	Product	Making decisions about the project, how and what to create or present and work.
Reflection		Reflecting on the journey throughout and at the end of the product. What they have learned, how they overcome the challenges, etc.
Critique and revision		Provide, receive, and apply feedback to improve their process and products.
Public product		Sharing and presenting their product beyond the classroom wall and into their larger community

3.4 Instruments

This section explains the instruments that were used to collect the different data for the study. The instrumentation plan is defined as several composed decisions and procedures that determine when what and how the data will be collected and analysed which includes not only the selection or design of devices but also the methods and conditions under which each instrument will be administered (Fraenkel, Wallen & Hyun 2012). These decisions direct the

study's course and help the researcher appropriately answer the research questions (Creswell 2014b).

The ability to use several instruments (four instruments) from the two types of approaches; quantitative and qualitative resulted in a comprehensive explanation of reality that could answer the study questions. Teachers' questionnaires, SSKT, MAP exam results, and teachers' interviews were among the instruments used. Referring to Bowen (2009), the availability of several sources of information allows the researcher to relate, compare, and obtain a clear picture of how opinions/ideas evolved over time, which leads to triangulation. This method-imposed time and effort for the researcher to be aware of and comprehend the study's phenomena in depth, as well as to ensure the quality of the mixed method approach.

3.4.1 Quantitative Tools and Procedures

3.4.1.1 Standardized Science Knowledge Test (SSKT)

To measure and analyze students' achievement, an SSKT was incorporated at the beginning and the end of each science project-based learning unit developed using the RCD model to measure students' achievement. The RCD-PBL curriculum units were implemented across all middle school classes (grades 6 to 8) for 6 to 8 weeks depending on the number of NGSS clustered standards found in each unit and making sure not to surpass 24 hours as per IB requirements. The pre and post-test results of the first units were computed to address the first research question "To what extent does rigorous curriculum design for project-based learning

implementation affect middle school students' achievement in science standardized knowledge test, in Abu Dhabi, UAE?''.

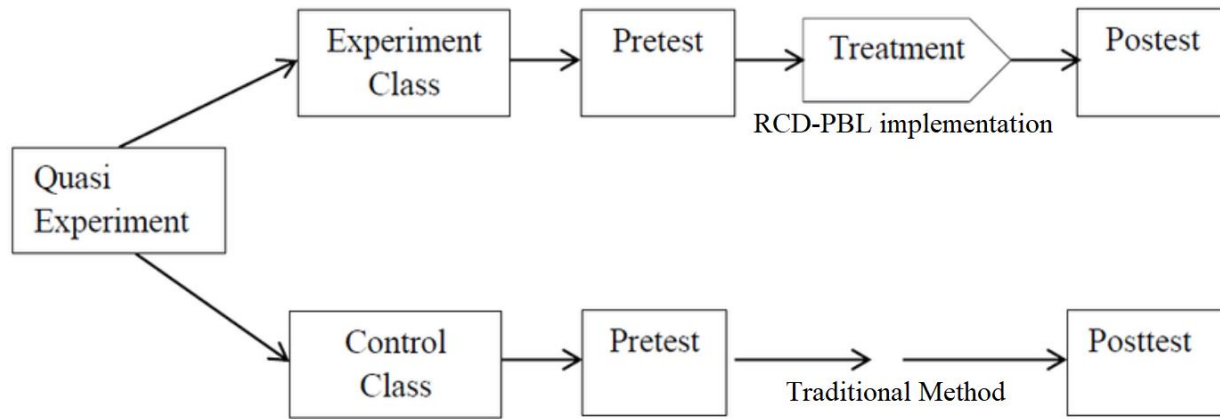


Figure 6: Quasi-experiment Pretest Posttest Non-Equivalent Control Group Design for SSKT

A Quasi-experiment pretest-posttest non-equivalent control group design method was used which involves an experimental group that is given a pretest, receives a treatment, and then is given a posttest and a control group that is given a pretest, does not receive the treatment, and then is given a posttest (Figure 6). Noting that the pretest and posttest incorporated for both groups are the same.

After conducting the pretest for all classes, the experimental and control group were selected. RCD-PBL was implemented as the treatment for the experimental group while no treatment was implemented in the control group whereby, the teacher continued teaching using the traditional method (textbook). The pre and post-SSKT were administered and shared with all students at the same time on teams through an MS Form link, whereby each student logged in using their school email address and credentials. Specific settings were set on forms in terms of date and time of submission along with one unified response for each student. All students were asked to turn their cameras on to monitor students' environment and make sure that the assessment properly reflects students' level. Students blended return to school was initiated during the second week of September. This meant that they were on a 4 days face-to-face and one-day virtual schedule. However, this learning mode was no longer offered as of January as per ADEK directives, whereby a full physical return was mandatory to all students except those with severe medical conditions.

SSKT pre-posttest results were generated from forms onto an excel sheet and then embedded in SPSS after administering a standardized science knowledge test based on each middle school grade level clustered standards and topics by addressing and meeting the performance expectation and observable features set for each set of standards.

Finally, to ensure the validity and reliability of this tool, the tests were written by a group of three to four middle school teachers from both boys' and girls' school campuses and reviewed by a panel of experts in the science field (subject coordinators, K-12 Science coordinator and RCD leaders) to make sure that the questions address all concepts that derived from the standards taught and are written based Depth of Knowledge levels. Based on the feedback, revision took place to address all recommendations, requests, and suggestions. Each test encompasses 15 questions, divided between Multiple choice and problem-solving questions, administered for 25 minutes to students at the beginning and at the end of the first unit of implementation. The tests were piloted and shared with 10 students from each grade level in the summer of 2020-2021 to grasp their feedback in terms of language, clarity, format, and the average time to answer these test questions. A sample of one pre-post science standard knowledge test is attached in Appendix C.

3.4.1.2 Measure of Academic Progress (MAP)

The Measure of Academic Progress is a nationally computerized exam of the NWEA that reports and measures the reliability and validity of its tests based on the results of millions of international students that take the test every year (NWEA 2012, 2016). It is different from traditional tests as 39 to 42 science questions based on Next Generation Science Standards test items adjust in level of difficulty. Furthermore, the MAP assessment test allows us to examine how far or below grade level the students are performing. A MAP testing schedule is set up and distributed to all science teachers. Before MAP testing takes place, an informative letter is sent to all parents by the school admin explaining what MAP testing is, its importance and when it is taking place as MAP testing is an ADEK requirement. Although the MAP test is typically untimed, one block of 90 min is allocated to perform the test during a science lesson to not lose any instructional time in other subjects. As it is a computerized exam, the MAP testing will take place in IT labs since MAP testing windows have been set up for all the personal computers found in the lab with all required safety measurements as indicated by the Ministry of Education

and health authorities. Both science and Information and Communications Technology (ICT) teachers have invigilated the classes to ensure proper exam conditions and safety measurements among students. In addition, ICT teachers' support in this process was very important to address any technical issue that arises and ensure a smooth testing session. The Researcher was one of the invigilators that monitored the process of MAP testing implementation as it was one of its keen job responsibilities at the school as well as to ensure triangulation and validity of the data. MAP testing was done twice per year in the Fall and in the Spring. The Fall 2021 and Spring 2022 scores were compiled and compared to provide a growth score for the year within the study timeframe to observe if more students met the growth target after the implementation of RCD project-based units. The RIT scale shows the change in students' academic growth and allows us to monitor their progress throughout the year. Growth targets were determined for each student, depending on the student's RIT scores in relation to the student's grade level national and international norms. For comparison, the researcher has relied on the norms data built in the MAP and based on 30 years of research and millions of test items responses as well as the projected growth generated for each student based on his/her RIT score ranges. During the academic year 2021-2022, the experimental groups were taught using RCD project-based units (Ainsworth 2011). After completing the MAP test, students' data results are collected electronically, and Achievement Status Growth projection report (ASG) was generated through the NWEA server.

For Descriptive analysis, the students' projected growth results generated from the ASG reports were classified and analyzed into four categories; the first one (Met growth) which indicates that the student attained the projected growth. The second category (Improved) which indicated that the student attained a better score in the MAP exam of Spring 2022 but did not meet the projected growth. The third category (Same level) student did not make any progress and stayed at the same level with the same score as MAP of Fall 2021; they neither improved nor declined. Finally, (Declined) which indicates that the student gained a low score in Spring 2022 compared to his/her score in Fall 2021.

Furthermore, independent sample t-test and one way ANOVA test were used to further address the second research questions as these results and analysis can be used as strong evidence in order to investigate the effect of using RCD-PBL on students' results in the MAP science exams for the current study.

3.4.1.3 Teachers' Questionnaire

The ideal way to obtain quantitative results was through answering survey questions such as questionnaire (Creswell 2014). The structured questionnaire was one of the instruments used to collect data in this study as it allowed the researcher to determine whether the information gathered and analyzed was generalized or specific (Saunders, Lewis & Thornhill 2019). The questionnaire was divided into four parts: demographics that embed teacher qualifications and experience, professional development, teachers' RCD-PBL receptivity, and finally teachers' understanding (RCD-PBL alignment and assessment in science) (Appendix D). These specific sections were chosen as they are the key factors that influence and impact the implementation and success of any curriculum.

The first part encompassed demographic questions related to campus, gender, mother tongue, teachers' years of experience, high level of qualification, grade level they are currently teaching, and previous experience in the American or IB curriculum. The second part of the questionnaire was related to professional development whereby teachers were asked to rate the degree of efficiency each training workshop whether RCD, PBL, or NGSS offered them using Likert scale questions ranging from strongly agree= 5, Agree=4, neither agree nor disagree=3, Disagree=2, strongly disagree=1. The third part of the questionnaire evaluated teachers' receptivity as it is a frontline for any curriculum implementation using a five-point Likert scale type of questions ranging from strongly agree= 5 to strongly disagree=1 to measure the value, practicality, and relevancy of a curriculum and teachers' confidence towards its implementation. In addition, since the questionnaire was shared with all middle school science teachers after Spring MAP testing took place and after four RCD-PBL units had been delivered, teachers were requested in this section to select the RCD design process key components areas they feel confident in while delivering RCD-PBL instructional units to students and evaluate the project-based learning science curricula units developed using the RCD model using Likert scale type of questions. Finally, the last part of the questionnaire requested the teacher to rate their agreement to each statement to evaluate the PBL curriculum in terms of alignment and assessment using a five-point Likert scale question. All these closed-ended questions were developed using an online platform called survey monkey whereby a link was shared with all middle school teachers involved in the RCD-PBL process in the school's daily bulletin board to increase participation (voluntary) and honesty in response. The participants were informed

participants whose informed consent, agreeing to participate in this study by clicking on “ I agree” button in the initial consent form questionnaire page after being informed of the research purpose, procedures, risks, benefits, confidentiality and anonymity was indispensable proceed to the next section of the questionnaire otherwise; it was terminated if consent was not provided. A period of three weeks was given to all middle school science teachers to complete the questionnaire with one reminder before the allocated deadline.

3.4.2 Validity and Reliability

Since this study followed an explanatory sequential mixed method approach, relying on numbers is a crucial factor for determining its finding. Hence, ensuring the validity and reliability of the instruments used based on the context was essential (Fraenkel, Wallen & Hyun 2015). Tests are essential tools that measure students’ learning (Benjamin & Pashler 2015) whereby their reliability was measured against the consistency of the scores obtained at different time intervals from several participants (Fraenkel, Wallen & Hyun 2015). In addition, these tools gain validity whenever appropriate and meaningful questions were designed or selected for prediction and investigation purposes (Fraenkel, Wallen & Hyun 2015).

Referring to the definition of validity and reliability, MAP test scores generated by NWEA were appropriate and consistent as these adaptive tests introduced to millions of students each year at different timing (Fall, winter, or spring) measures students’ academic growth and progress in line with the multidimensional set of NGSS standards found in this adopted curriculum (NWEA 2016). Furthermore, while several types of validity exist, the science knowledge Pre-Post test results along with the questionnaire were checked against content-related validity to ensure the appropriateness of the content and logical structure of both instruments (Fraenkel, Wallen & Hyun 2015). To guarantee the appropriateness and comprehensive content adopted in the science knowledge test, a group of 3 to 4 middle school teachers have collaborated in developing these tools that were examined and reviewed by a panel of experts in the science field such as subject coordinators, K-12 Science coordinator and RCD leaders to make sure that questions addressed all concepts derived from the standards and are written based Depth of Knowledge levels. Moreover, the test-retest method was one way of measuring the reliability of these research tools whereby the same test was administered to the same group at two different time intervals (beginning and after 6-8 weeks of implementation) and a reliability coefficient was calculated ranging from 0.00 to 1.00 to ensure consistency

(Fraenkel, Wallen & Hyun 2015). Cronbach's alpha coefficient was used to determine the reliability and internal consistency of the 17 items SSKT questions. The results of the reliability test were $\alpha = 0.701$ indicating that the SSKT items are consistent and reliable as shown in Table 8.

Table 8: Reliability Pilot Test Result of SSKT

Reliability Statistics	
Cronbach's Alpha	N of Items
.701	17

In every research study, piloting is a useful method for clarifying the statement of investigation, the study's questions, and the measurement process (Glesne 2006). The primary reason for piloting, according to Fraenkel, Wallen, and Hyun (2015), was to ensure validity and reliability. Although a pilot study may not ensure the achievement of the inquiry, it increases the chances of progress, and help in the feasibility and attainability of inquiry since it is thought to be a smaller version of a full-scale examination (Van Teijlingen & Hundley 2005). Subsequently, a pilot study was done as a small-scale methodological test (Fraenkel, ss & Hyun 2012).

While some parts of the questionnaire adopted were previously tested for validity and reliability as they were selected and modified from the survey used in New Zealand to evaluate curriculum implementation (Sinnema 2011), others have been developed by a group of RCD leaders and reviewed by the school general director, the director of Education, and by two experts in the field of curriculum to ensure content validity by affirming that the types of questions added and their details are relevant, appropriate, and reflects the constructs investigated in the study purpose. Once the questionnaire was finalized and all experts' comments and feedback were addressed, it was then communicated to 10 middle science teachers randomly chosen from the two campuses. Based on the pilot test feedback and input communicated by the participants, adjustments and modifications were made to the questionnaire. For example, receptivity was added as a section with sub items (such as flexibility, practicality, confidence, workload) that reflects its definition rather than an item to be evaluated by the teachers that may not know its prior meaning or definition. In addition,

percentage were added next to the Likert scale items when evaluating the improvement in their students' achievement in the pre-post unit assessment for e.g Strongly Agree reflects that more than 75% of the students have improved in their SSKT pre-post test results. Furthermore, to ensure and check the inter-item reliability between the 63 items of the questionnaire, Cronbach's alpha was calculated after transferring all data to SPSS. According to Cohen, Manion, and Morrison (2007, 2017) a Cronbach's alpha higher than 0.9 is considered very highly reliable; between 0.80-0.90 highly reliable; 0.70-0.79 reliable; and between 0.60-0.69 marginally reliable. The results of the reliability test of this current study was $\alpha = 0.913$ indicating that the questionnaire items are consistent and very highly reliable as shown in Table 9. Furthermore, the inter-rater reliability for the pilot study assessed using the intra-class correlation coefficient has shown to be significant (< 0.00) indicating good correlation and reliability between the items tested as observed in Table 10.

Table 9: Reliability Pilot Test Result of Teachers' Questionnaire

Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.908	.913	63

Table 10: Inter-Rater Reliability Pilot Test Results

Intraclass Correlation Coefficient							
	Intraclass Correlation ^b	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.135 ^a	.061	.358	10.820	9	558	.000
Average Measures	.908 ^c	.803	.972	10.820	9	558	.000

Two-way mixed effects model where people effects are random and measures effects are fixed.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C intraclass correlation coefficients using a consistency definition. The between-measure variance is excluded from the denominator variance.

c. This estimate is computed assuming the interaction effect is absent, because it is not estimable otherwise.

3.4.3 Qualitative Tools and Procedures

3.4.3.1 Teachers' Interviews

As depicted in Appendix E, the researcher conducted interviews with middle school science teachers that were selected to deliver the RCD-PBL curriculum from grades 6 to 8 to

follow up and acquire a deeper understanding of the responses related to the questionnaire and study questions. Referring to Fraenkel, Wallen, and Hyun (2015), an interview is an oral response to structured questions designed to acquire information from the subject, with a reasonable opportunity to clarify probes and study the participants' responses further as needed. Furthermore, interviews allow and enable the researcher to address a variety of concerns in the research study by ensuring the relevancy and validity of the data acquired. This instrument provides a deeper insight and understanding of the participants' opinions (Seidman 2013) and hidden thoughts (Fraenkel, Wallen & Hyun 2015). As there is a high possibility of only having one opportunity to interview the participants due to teachers' load, external professional development sessions, unavailability, and much more, semi-structured interviews were recommended (Seidman 2013). This type of interview is the most effective and convenient type that meets the purpose of the study (Kvale & Brinkmann 2009) whereby building a two-way discussion allows the researcher to respond and reflect in an appropriate way (Creswell 2009).

In this study, the semi-structured interview questions were developed by the researcher after reviewing the available literature and based on the outcome of the questionnaire and the quantitative data (Fraenkel, Wallen & Hyun 2015). The interviews were conducted with the six middle school science teachers who were assigned to deliver the RCD-PBL curriculum based on their years of experience in the school and were involved in the RCD, PBL, and NGSS PD sessions that were conducted over the course of the academic years 2020-2021 and 2021-2022. The middle school science teachers' interviews target to shed light on their perceptions towards rigorous curriculum design for project-based learning development and implementation in science. In addition, it provided them with several opportunities to clarify the relationship between grasping their perceptions towards their involvement in the development and implementation of such curriculum and its effectiveness on students' outcomes and be able to elaborate and provide a future recommendation. The interview questions were mainly based on the RCD design framework model, RCD-PBL effectiveness and impact, receptivity, challenges, professional development, teacher involvement, students' achievements, and recommendations based on the quantitative data results. These main categories were chosen after grasping three teachers' feedback on the questions set. For instance, the number of questions, categories, probes and the structure of the questions were either modified, compiled, added or changed. Examples are reflected in the Table 11. In addition, three experts in the field have reviewed the

interview questions as part of the validation process. This procedure was followed to ensure that the instrument was measuring what it was supposed to, represented the study content, was appropriate for the research study's sample population, and that it was comprehensive. As for the external validity, which may arise due to incorrect assumptions or bias during the collection of qualitative data (Fraenkel, Wallen & Hyun, 2014), this was excluded from the study's investigation's design as the researchers adopted a sequential mixed method approach in which the quantitative method was used first, followed by the qualitative method, in order to grasp the substantial changes that occurred with both teachers and students.

Table 11: Interview Questions Pilot Study Modifications Examples

Piloted Questions	Questions Modifications
RECEPTIVITY - How confident were you towards implementing these PBL units for the first time? - What did you like the most about these RCD-PBL science units? - How relevant were these RCD-PBL science units compared to the textbook curriculum?	RECEPTIVITY & CHALLENGES - How has your perception and confidence of PBL evolved since first encountering the instructional model? - What did you like the most about these RCD-PBL science units? - How relevant were these RCD-PBL science units compared to the textbook curriculum? - What hindrances and difficulties did you encounter as you attempted to implement these units? - Were these challenges overcome through time? How?
CHALLENGES - What hindrances did you encounter as you attempted to implement these units? - How difficult was it to implement PBL?	
INVOLVEMENT - Do you think your involvement, choice, and collaboration with other colleagues have helped set up such a curriculum? - How did the collaboration and involvement of teachers towards designing PBL units using the RCD process reduce the time related to building lesson planners and assessments?	INVOLVEMENT - To what extent do you think your involvement, choice, and collaboration with other colleagues were essential to developing and implementing such a curriculum? - To what extent do you think that the collaboration and involvement of teachers towards designing PBL units using the RCD process has reduced the time related to building lesson planners and assessments?
STUDENTS' ACHIEVEMENT Looking at Fall-Spring MAP data, how did the RCD-PBL curriculum impact the MAP scores results?	STUDENTS' ACHIEVEMENT - Looking at Fall-Spring MAP data, how did the RCD-PBL curriculum impact the MAP scores results? - In case there was no/weak development in students' results, what are the reasons behind that? Any Recommendations?

The six middle school science teachers were requested to answer the interview questions through video call meetings on Microsoft Teams as face-to-face meetings were still restricted due to the pandemic. Conducting interviews with a variety of participants who work in the same field increases effectiveness through social interaction (Fraenkel, Wallen & Hyun 2012). Therefore, participants were asked if they could turn on their cameras to allow for more interactions and elaborated answers as opposed to collecting data using a questionnaire.

While some participants were gleaned from an Arab-speaking populace, they were also eloquent in the English language. This is especially due to the fact that teachers recruited at this school are required to take a language acquisition test (IELTS) and achieve a score of 7.5 whether or not they are English native speakers. Therefore, based on the interviewees' preferred language, the interview sessions were held in English and were scheduled to take place during Continuing Professional Development (CPD) sessions at the school where the research study is taking place. Each interview session was conducted for about an hour and was recorded after taking the participants' consent to revisit information once needed and eliminate misinterpretation of the transcripts. Furthermore, sharing the interview transcripts with the interviewees empowered the participants, involved them in the study, and ensured the validity of the transcripts by confirming that what was mentioned and shared in the interview reflects what was transcribed (Hagens, Dobrow & Chafe 2009; Mero-Jaffe 2011). Lastly, RCD leaders were asked to review the interview transcripts' emerging themes and help in reviewing the process of analysis to validate and enhance the credibility of the qualitative findings, which in return will increase and strengthen the trustworthiness of the research study.

3.5 Data analysis

As the research study follows an explanatory sequential mixed method, the quantitative data were collected and analyzed first followed by the qualitative data to support the results. The quantitative data of this study was collected using the science standard knowledge test, MAP scores, and teachers' questionnaire. To answer the research questions and obtain the desired results by evaluating the data, descriptive statistics such as mean, standard deviation as well as inferential statistics were computed by the researcher. Descriptive statistics are considered the groundwork of this type of data whereby it is used to summarize, describe, and make sense of data set. Inferential statistics are used in this study to help the researcher to move beyond the immediate data and infer about population characteristics based on samples.

In order to address the first research question, the science standards knowledge test Pre-Posttest scores were collected by the researcher from both the experimental and control group and were exported to SPSS from the Excel sheets generated from MS Forms where the test was developed and shared with students during their science classes at the beginning and end of the first unit. Descriptive statistics on variables are shown and statistical hypothesis tests are used in statistical inference, to decide whether sample data on the improvement in SSKT mean scores, using pre-test and post-test SSKT scores, sufficiently support a particular hypothesis at the 5% level of significance. T-tests and statistical tests were used in hypothesis testing, to test if there are significant differences between two sample means at the 5% level of significance. A Paired sample t-test was the most convenient statistical technique to use when comparing continuous variables such as test scores to measure if there is a statistically significant difference in terms of students' academic achievement means in science between the experimental and control group per grade level. In addition, the effect size for paired sample t-test was calculated using Cohen's d to interpret the strength of this educational intervention whereby, an index value of $d=0.20$, $d=0.50$, and $d=0.80$ or greater indicates respectively a small, medium, and large practical significance between the two treatment groups (Cohen 1992). Paired t-tests are more powerful than unpaired t-tests because they eliminate the variation between samples produced by anything other than the thing being tested. In addition, an independent sample t-test was done in order to analyze the variable improvement which is equal to the post-test minus the pre-test SSKT scores for grades 6, 7, and 8 separately and all grades combined. The variable improvement was analyzed for the control and experimental groups. Levene's F test was used to test for the equality of variances between the control and experimental groups. Where there was a violation of the assumption of homogeneity of variances, the Welch robust F-test of equality of means was used since the Welch test does not assume the homogeneity of variances assumption. Cohen's d -test for independent sample t-test was also calculated to determine the effect size. Normality tests were done for the independent sample t-test and the paired sample t-tests using the Kolmogorov-Smirnov test, the Shapiro-Wilk test, and normal probability (P-P plot) in SPSS. A one-way analysis of variance (ANOVA) was also performed on the improvement in SSKT scores for grades 6, 7, and 8 to test if there is a statistically significant difference between the grade levels. Moreover, a two-way ANOVA on the improvement in SSKT scores was also done for each grade (6, 7, and 8) for the four groups: control female,

control male, experimental female, and experimental male to find out if there is interrelationship between the independent variables, grade levels and group on the dependent variable, mean SSKT improvement. The advantage of an ANOVA is that it may withstand violations of the normality assumption better than a t-test. Fisher's least significance difference (LSD) and Tukey honestly significant difference (HSD) post hoc tests were used to show if there were statistically significant ($p < .05$) differences in the improvement in SSKT scores between various groups, grades, grade*group at the 5% level of statistical significance.

Furthermore, to address the second research question, descriptive statistics were analyzed from the ASG generated reports from NWEA, whereby graphs were generated from Excel sheet showcasing the number of students that have Met growth, improved, stayed the same, or declined between experimental and controlled groups per grade level. Followed by an independent sample t-test to compare the mean between the two groups to find if there is a statistical significance between, RCD project-based learning versus textbook curriculum (non-PBL), for the same dependent variable, MAP growth. Levene's F test for equality of variances and Cohen's d test for independent sample t-test were also carried out. In addition, one-way ANOVA was also used as the second mean of analysis to determine whether the two independent variables demonstrated a significant difference between student MAP growth scores of students taught using a traditional textbook-based curriculum versus the RCD-PBL curriculum.

Finally, the third research question is twofold, quantitative (Teacher questionnaire) and qualitative (Semi-structured interview). To address the first part of this research question, the researcher analysed the responses of teachers from the questionnaire survey. Teachers' survey questionnaire was taken online whereby each response received was anonymous and referred to e.g. participant or respondent 1, to maintain anonymity and increase teachers' honesty in responses. It was administered to grasp teachers' perceptions towards rigorous curriculum design adoption for project-based learning development and implementation in science. The survey questionnaire was tallied utilizing Survey Monkey and the data were computed, compiled, and analyzed (descriptively and statistically) in the platform. Furthermore, all data were downloaded into an Excel spreadsheet and then embedded in SPSS to measure the tool reliability by calculating Cronbach alpha.

Finally, to address the second part of the third research question, qualitative data was collected through semi-structured interviews, whereby the recordings were analyzed using the thematic analysis process (Creswell 2014b). Adopting such an approach helps to identify, analyze, clarify and report common themes from patterns within the raw data while organizing and describing the data in detail (Braun & Clarke 2006). This particular approach is best used when the research study entails grasping teachers' perceptions, opinions, experiences, and more from a set of qualitative data such as interview transcripts (Caulfield 2022). Interview sessions invitation links via Microsoft Teams with the suggested times and dates were sent out to the participating teachers. The interview sessions were conducted for one hour with camera on. All recordings and interviewees anonymity remained confidential. All interviewees' recordings have been transcribed and analysed by the researcher who made sure that every statement was recorded and noted. Furthermore, a copy of the transcript was shared with each interviewee to allow them to revisit and review their interview responses in written form in order to validate the content of the transcribed data before proceeding to the analysis process. While interview questions were divided into categories, the researcher examined interviewees' responses question by question and highlighted similar response statements using the same color to track their frequency, identify emerging themes, and denote patterns. While there are several approaches to conducting thematic analysis, the six-step process of Virginia Braun and Victoria Clarke has been adopted in this study (Table 12): 1. Familiarisation 2. Coding, 3. Generating themes, 4. Reviewing themes, 5. Defining and naming themes, and 6. Report (Braun & Clarke 2006, p.87). QDA Miner Lite v2.0.9 Free Edition was used to analyze the qualitative data from the 6 interview transcripts. The data gained from the qualitative generic thematic analysis process provided a comprehensive foundation for understanding a global theme, thereby supporting the researcher's themes (Aronson 1995) that were reviewed and discussed with other experts and RCD leaders for further validation. The output of the qualitative analysis of the 6 interview transcripts are shown in the analysis section of chapter 4. Finally, QDA MINER LITE v2.0.9 Free Edition which is a mixed techniques and qualitative data analysis software tool that aids in qualitative data management, coding, and analysis for researchers was used to show the interview transcript question, count, percentage codes, cases, and percentage cases.

Table 12: Summary Steps of Braune and Clarke's thematic Analysis Process

Steps	Description of the process
Step 1. Familiarisation with data	Conducting a thorough review of all collected data. This could be accomplished by transcribing, reading, and re-reading the data, as well as noting down initial ideas.
Step 2. Coding	Collating interesting features of data (by highlighting phrases or sentences) to relevant codes or labels that recur across the entire set of collected data to describe the content.
Step 3. Generating themes	Identifying patterns among the codes generated and generating potential themes.
Step 4. Reviewing themes	Checking the accuracy and usefulness of the themes in rapport with the codes extracted and the entire data.
Step 5. Defining and naming themes	Defining and naming each generated theme helps in understanding the data in a clear manner.
Step 6. Report	Producing the report of the analysis by selecting compelling and vivid extract examples and relating them back to the study research question.

3.6 Ethical consideration

Adhering to ethical procedures by respecting individuals and sites was essential to ensure the validity, integrity, and anonymity of participants in any research study (Creswell 2012). Therefore, authorized written consents were gained every step of the way. Firstly, as the research study focused on investigating the effectiveness of the implementation of RCD-PBL in grades 6 to 8 classes (middle school students), a meeting was conducted with the campus director not only to explain the research study purpose, process, data collection and ensure that students identities and school name will remain anonymous but to also seek his approval and consent to conduct the research study in this respective campus. Once the approval was granted from the institution, a paper generated by the school campus director was submitted to the British University in Dubai (BUiD) research ethic committee for which it highlighted the approval and acknowledgment of the school and all its members towards the implementation of the RCD-PBL in grades 6-8 (Appendix F). When the ethical research form was approved by the committee, an official letter was issued from the British University in Dubai and shared with the school campus director to initiate the research study (Appendix G).

Secondly, as the implementation was conducted in the middle school cycle, whereby students are considered vulnerable participants, an informative session was conducted with parents at the beginning of the academic year whereby the research purpose, questions, and data collection methods were explained, and the anonymity of their children's names was assured. Therefore, the researcher replaced all the names of the students that participated in the MAP exam scores and SSKT with numbers. Thirdly, an informative letter was sent to all parents by the school admin informing them what is MAP testing, its importance and when it is taking place given that it is an ADEK requirement.

Since confidentiality and anonymity are the most essential ethical considerations that should be available in every research study (Wiles et al. 2008), they were maintained through the collection of teacher questionnaires submitted online, both voluntarily and anonymously. The researcher's relationship with teacher participants was not one of the direct supervisory roles and would not impact their work. Informed consent was communicated to all participating teachers in the study through the questionnaire introduction section. All consent forms introduced the researcher and purpose of the study, acknowledged participants' rights to refrain from participation with no penalties and ensured the confidentiality and anonymity of participants. All consent forms were saved in one folder.

Lastly, all participants were informed about the interview procedures and questions beforehand. Interview consent forms which entail a description of the research study were communicated to all participating teachers by email (Appendix E). In addition, teachers were asked for their consent to record the interview session whereby the researcher assured the participants that the recordings will remain confidential and will be deleted after the data has been transcribed. Invitation links via Microsoft Teams with the suggested times and dates were sent out to the participating teachers. Interview consent forms signed by participants were collected and compiled in one place on the drive. All interview recordings remained confidential and will not be shared with anyone in the school other than the researcher. The recordings were stored in a password-protected file on the computer and were deleted once they were transcribed and validated by the interviewees. All interviewees' names were replaced by numerical numbers (e.g. Interviewee 1, respondent 1) to maintain participants' anonymity. Sharing the interview transcripts with the interviewees has ensured the validity of the transcripts (Hagens, Dobrow & Chafe 2009; Mero-Jaffe 2011). Finally, during the interviews, the researcher focused on the

ethical code of conduct in order to avert any complications related to personal information or sensitive data that may be revealed during the data collection stage (Johnson & Christensen 2014).

CHAPTER IV: DATA ANALYSIS AND RESULTS

4.1 Overview

This chapter presents the analysis of the data collected from the participants of the current study with the aim of addressing the below research questions posed in order to investigate the effectiveness and teachers' perceptions towards the Rigorous Curriculum Design for project-based learning (RCD-PBL) implementation on middle school science students' achievement and MAP scores, in Abu Dhabi, UAE.

RQ1: To what extent does rigorous curriculum design for project-based learning implementation

affect middle school students' achievement in science standardized knowledge tests, in Abu Dhabi, UAE?

RQ2: To what extent does rigorous curriculum design for project-based learning implementation

affect middle school science students' MAP scores in Abu Dhabi, UAE?

RQ3: What are middle school teachers' perceptions towards rigorous curriculum design for project-based learning development and implementation in science?

A mixed-method approach was used to achieve the objectives of the study. Quantitative and qualitative data analysis results constitute the main sections of this chapter whereby each of the preceding questions helps in identifying the suitable analytical technique and approach to ensure that the data obtained can provide a complete answer to each question while also effectively addressing the research topic.

The identification of the experimental group (RCD-PBL implementation) and control group (Traditional textbook-based curriculum) from which data was collected was based on similar demographics, pre-test results, and similar standard deviation deriving from their Measure of Academic Progress (MAP) Fall to Winter 2020-2021 scores in each grade level. Descriptive and inferential statistics were conducted to address the first research question whereby independent sample t-tests on the improvement in Standardized Science Knowledge Test (SSKT) scores and paired sample t-tests on pre-test and post-test SSKT scores were performed. The paired sample t-test was conducted to measure if there is a statistically significant difference in terms of students' academic achievement means in science between experimental and control groups. In addition, the effect size using Cohen's *d* was calculated to

interpret the strength of this educational intervention. Furthermore, the independent sample t-tests were done on the mean improvement in SSKT scores for grades 6,7, and 8 combined and separately to find if there is a statistical significance between RCD project-based learning versus textbook curriculum for the same dependent variable SSKT score for all grade levels one-way Analysis of Variance (ANOVA) on the mean improvement was carried out in order to find out if there are any significant differences in mean improvement for the three grades (6, 7, and 8). A two-way ANOVA was performed to find out if there are any significant differences between the four groups (control female, control male, experimental female, and experimental male) in mean improvement in SSKT scores for each grade.

In addition, students' Fall 2021 to Spring 2022 MAP scores were analyzed to examine if more students met the growth target and had higher mean achievement in MAP scores after the implementation of RCD project-based curriculum units. Descriptive and inferential statistics were used to address the second research question. An independent sample t-test was conducted to compare the mean between the two groups to find if there is a statistical significance between, RCD project-based learning versus textbook curriculum (non-PBL), for the same dependent variable, MAP growth for grades 6, 7, and 8. An ANOVA on MAP growth for Grades 6, 7, and 8 was also carried out to verify the results. The Kolmogorov-Smirnov test and Shapiro-Wilk test were used to check for normality for each group in the independent sample t-test and the paired differences in the paired-sample t-tests (see Appendix H) as the sample sizes were either less or more than 50.

Subsequently, the researcher analysed the responses of all teachers from the questionnaire survey to explore their perceptions and demographics toward rigorous curriculum design for project-based learning development and implementation in science. After analyzing the questionnaire survey responses, the researcher analysed the interview responses of various teachers using thematic analysis. Finally, data triangulation was done to validate the qualitative data with the quantitative results.

4.2 Quantitative Data Results Analysis

This section presents the first step in the explanatory sequential mixed method design adopted in this study which begins with the quantitative part. It covers the results of students in both the Science Standards Knowledge Test and MAP exams scores as well as the teachers' questionnaire responses.

4.2.1 Normality test

Before a t-test was conducted, the data variables were checked for the assumption of normality using the Kolmogorov-Smirnov test, Shapiro-Wilk test, and the normal probability plot (P-P plot). While Shapiro-Wilk is the most powerful normality test, it is usually used for a small sample size of 50 or less (such as control or experimental groups); however, it can also be used for a larger sample just as the Kolmogorov-Smirnov test that can be used for a sample size greater than 50 (all grade levels combined or paired) (Bee Wah & Mohd Razali 2011). The normality tests for the independent sample t-tests and the paired sample t-tests are represented in Appendix H. Data is normally distributed if $p > .05$ in the Shapiro-Wilk test and the Kolmogorov-Smirnov test. The P-P plot was used to check if there were serious outliers or if the distributions of data were far from normal. Results from Appendix H show that although there were some violations of the normality assumption, there are no serious outliers, and the sample sizes are large. Boneau (1960), in his study on the effects of violation of assumptions underlying the t-test, found empirically that the t-test is rarely influenced when the data does not meet the assumptions. Given that the two sample sizes are identical or nearly equal, and that the hypothesized underlying population distributions are of the same shape or nearly the same, Boneau (1960) found that the t-test was resistant to violations of a number of assumptions. The validity of this test is only questioned in cases where there may be significant outliers (long-tailed distributions), or in cases where sample sizes are small ($n < 25$) and distributions are out of the ordinary which is not the case in this study.

4.2.2 Results of Student's Achievement in SSKT

In this section, the analysis and results of the first research question: To what extent does rigorous curriculum design for project-based learning implementation affect middle school students' achievement in science standardized knowledge tests, in Abu Dhabi, UAE? were presented.

The SSKT was introduced at the beginning as a pre-test and at the end as a post-test of the first unit of implementation for both the experimental and control groups. Two middle school campuses that follow the American curriculum in the Emirates of Abu Dhabi, in the United Arab Emirates, participated in the current study whereby the collected sample represents (N=304) middle school Emirati students from grades six to eight. Students were separated by gender from grade 5. The study pre-post test data was collected from 12 science classes whereby

6 classes implemented the RCD-PBL curriculum units (experimental group) and 6 classes followed the traditional textbook-based curriculum (control group). The sample included two classes for males (experimental and control) and two classes for females for each grade level. The results were gathered on an excel sheet and descriptive and inferential statistics were analysed through Statistical Package for Social Sciences (SPSS). Paired sample t-test, independent sample t-test, and analysis of variance (ANOVA) were performed and analysed to answer the first research question.

In order to study the effect of RCD-PBL on students' achievement in SSKT we intended to find:

- If there is a statistical significant difference in terms of students' academic achievement means in science between experimental and control group pre-posttest scores (Paired sample t-test).
- If there is a statistical significance in the mean improvement in SSKT scores between, RCD project-based learning versus textbook curriculum, for the same dependent variable SSKT score for all grade levels separated and combined. (Independent sample t-test).
- If there are any significant interaction in mean improvement between the three grades (6, 7, and 8) and the teaching method and gender (control female, control male, experimental female, and experimental male) on mean improvement in SSKT scores. (Two-way ANOVA).

4.2.2.1 Paired Sample t-test for SSKT

A paired samples t-test is used to compare the difference between the experimental and control groups for pre-test and post-test SSKT scores. The null and alternative hypotheses for the paired-samples t-test for RQ1 are:

- $H_0: \mu_d = 0$, There is no statistical significant difference in terms of the students' academic achievement means in science SSKT between experimental and control group Pre-Post test scores.
- $H_a: \mu_d > 0$, There is a statistical significant difference in terms of students' academic achievement means in science SSKT between experimental and control group Pre-Post test scores.

where μ_d is the difference between the mean pre-post-test results of the experimental group and the control group.

Grade 6 Control Group

A paired-samples t-test was conducted to compare pre-tests and post-tests scores for the control group in Grade 6. There was a significant difference in the scores for pre-tests (Mean=7.725, Standard deviation=2.8919) and post-tests (M=10.588, SD=2.4509) at the 5% and 1% levels of significance ($t(50) = -14.751, p < .001$) as illustrated in Table 13.

Table 13: Statistics and Paired T-Test for Grade 6 Control Pre-Test and Post-Test SSKT Scores

		Mean	N	Std. Deviation		Std. Error Mean			
Pair 1	Pre-test/15	7.725	51	2.8919		.4049			
	Post-test/15	10.588	51	2.4509		.3432			
		Paired Differences					df	Sig. (2-tailed)	
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower				Upper
Pair 1	Pre-test/15 Post-test/15	-2.8627	1.3859	.1941	-3.2525	-2.4729	-14.751	50	.000

The mean difference between pre-test and post-test scores is -2.8627 suggesting that the mean change for these pairs is significantly different from zero. Therefore, for the control group of grade 6, there was a mean gain of 2.8627 for the average student in the SSKT. Since $p < .05$, we reject the Null hypothesis ($H_0: \mu_d = 0$) and conclude that for the grade 6 control group the pre-test and post-test difference in SSKT is significantly different from zero. This means that even without the RCD-PBL, a Grade 6 student on average performed better in the post-test SSKT than in the pre-test SSKT by 2.8919.

For the paired-sample t-test, Cohen's d test:

$$d = \frac{\text{mean difference}}{\text{standard deviation of difference}}$$

$$d = \frac{2.8627}{1.3859} = 2.07,$$

therefore, the effect size is large. A d of 2.07 indicates that SSKT pre-test and post-test scores of the grade 6 control group differ by 2.07 standard deviations.

Grade 6 Experimental Group

Similarly, a paired t-test for the experimental group was conducted to compare pre-tests and post-tests scores for the experimental group in grade 6 and the output represented in Table 14 indicates that the mean for the pre-test is 7.745 and 12.549 for the post-test scores. There was a significant difference in the scores for pre-tests (M=7.745, SD=2.4400) and post-tests (M=12.549, SD=1.9730) at the 5% and 1% levels of significance ($t(50) = -19.297, p < .001$).

Table 14: Statistics and Paired T-Test for Grade 6 Experimental Pre-Test and Post-Test SSKT Scores

		Mean	N	Std. Deviation		Std. Error Mean			
Pair 1	Pre-test/15	7.745	51	2.4400		.3417			
	Post-test/15	12.549	51	1.9730		.2763			
		Paired Differences						df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pre-test/15 Post-test/15	-4.8039	1.7779	.2490	-5.3040	-4.3039	-19.297	50	.000

The average difference between the pre-test and post-test scores is -4.8039. This means that an average student gained a score of 4.8039 from the RCD for PBL. The null hypothesis at the 5% and 1% level of significance was rejected since $p < .001$. The sample data support the notion that the average paired difference does not equal to zero specifically, as the post-test mean is greater than the pre-test mean. The 95% confidence interval estimates that the actual population difference between the pre-test and post-test is likely to be between -5.3040 and -4.3039. The negative values reflect the fact that the pre-test has a lower mean than the post-test (i.e., pre-test – post-test < 0). The confidence interval excludes the value of zero (no difference between groups), thus the RCD-PBL results in a significant increase in the SSKT scores. For the experimental group, it is shown that the post-test scores are significantly better than the pre-test scores by an average of 4.8039. For the paired-sample t-test, Cohen's d test:

$$d = \frac{4.8039}{1.7779} = 2.7,$$

therefore, the effect size is large. A d of 2.7 indicates that SSKT pre-test and post-test scores of grade 6 experimental group differ by 2.7 standard deviations.

Grade 6 Control and Experimental Groups

Comparing the control and experimental groups of grade 6, the statistical analysis shows that there is a higher mean gain in SSKT scores for the experimental group than the control group. The mean pre-test scores of 7.725 and 7.745 of the control group and the experimental group respectively are almost the same and it is therefore reasonable to compare their post-test scores on SSKT. An average student in the experimental group gained 4.8039 points on the SSKT as compared to a student in the control group who gained an average of 2.8627.

Grade 7 Control Group

A paired-samples t-test was conducted to compare pre-tests and post-tests scores for the control group in grade 7. There was a significant difference in the scores for pre-tests ($M=6.904$, $SD=2.5380$) and post-tests ($M=10.750$, $SD=2.4405$) at the 5% and 1% levels of significance ($t(51) = -12.082$, $p < .001$) as illustrated in Table 15.

Table 15: Statistics and Paired T-Test for Grade 7 Control Pre-Test and Post-Test SSKT Scores

		Mean	N	Std. Deviation		Std. Error Mean			
Pair 1	Pre-test/15	6.904	52	2.5380		.3520			
	Post-test/15	10.750	52	2.4405		.3384			
		Paired Differences						df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pre-test/15 Post-test/15	-3.8462	2.2956	.3183	-4.4853	-3.2070	-12.082	51	.000

The average difference between the pre-test and post-test mean scores is -3.8462, suggesting that the mean change for these pairs is significantly different from zero. Therefore, for the control group of grade 7, there was a mean gain of 3.8462 for the average student in the SSKT. The null hypothesis ($H_0: \mu_d = 0$) at the 5% and 1% level of significance was rejected since

$p < .001$. For the grade 7 control group, it is observed that there is a significant difference in students' achievement in SSKT. For the paired-sample t-test, Cohen's d test:

$$d = \frac{3.8462}{2.2956} = 1.68,$$

therefore, the effect size is large. The SSKT pre-test and post-test scores of the grade 7 control group differ by 1.68 standard deviations.

Grade 7 Experimental Group

A paired t-test for the experimental group was conducted and results show that the mean for the pre-test is 7.040 and 12.000 for the post-test scores as observed in Table 16. There was a significant difference in the scores for pre-tests (M=7.040, SD=2.2854) and post-tests (M=12.000, SD=2.0102) at the 5% and 1% levels of significance ($t(49) = -16.945$, $p < .001$).

Table 16: Statistics and Paired T-Test for Grade 7 Experimental Pre-Test and Post-Test SSKT Scores

		Mean	N	Std. Deviation		Std. Error Mean			
Pair 1	Pre-test/15	7.040	50	2.2854		.3232			
	Post-test/15	12.000	50	2.0102		.2843			
		Paired Differences						df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pre-test/15 Post-test/15	-4.9600	2.0698	.2927	-5.5482	-4.3718	-16.945	49	.000

The average difference between the pre-test and post-test mean scores is -4.9600. This means that an average student gained a score of 4.9600 from the RCD for PBL. The null hypothesis ($H_0: \mu_d = 0$) at the 5% and 1% level of significance was rejected since $p < .001$. The sample data support the notion that the average paired difference does not equal zero. Specifically, the post-test mean is greater than the pre-test mean. The 95% confidence interval estimates that the actual population difference between the pre-test and post-test is likely to be between -4.3718 and -16.945. The confidence interval excludes the value of zero, so we can conclude that the RCD for PBL results in a significant increase in the SSKT scores. For the experimental group, we conclude that the post-test scores are significantly better than the pre-test scores. For the paired-sample t-test, Cohen's d test:

$$d = \frac{4.96}{2.0698} = 2.4,$$

therefore, the effect size is large. The SSKT pre-test and post-test scores of grade 7 experimental group differ by 2.4 standard deviations.

Grade 7 Control and Experimental Groups

Comparing the control and experimental groups of Grade 7, the statistical analysis shows that there is a higher mean gain in SSKT scores for the experimental group than the control group. The mean pre-test scores of 6.904 and 7.040 of the control group and the experimental group respectively are almost equal and therefore it is reasonable to compare their post-test scores on SSKT. An average student in the experimental group gained 4.9600 points on the SSKT as compared to a student in the control group who gained an average of 3.8462.

Grade 8 Control Group

A paired-sample t-test was done to compare pre-tests and post-tests scores for the control group in grade 8. There was a significant difference in the scores for pre-tests ($M=5.200$, $SD=2.8212$) and post-tests (mean=9.600, standard deviation =3.0506) at the 5% and 1% levels of significance ($t(49) = -9.090$, $p < .001$) as observed Table 17. The mean difference between pre-test and post-test scores is -4.400, suggesting that the mean change for these pairs is significantly different from zero. Therefore, for the control group of grade 8, there was a mean gain of 4.400 points for the average student in the SSKT. As the null hypothesis ($H_0: \mu_d = 0$) at the 5% and 1% level of significance was rejected since $p < .001$, this means that there is a significant difference in pre-test and post-test SSKT scores. The post-test scores are significantly higher than the mean pre-test scores for an average grade 8 student in the control group.

Table 17: Statistics and Paired T-Test for Grade 8 Control Pre-Test and Post-Test SSKT Scores

		Mean	N	Std. Deviation		Std. Error Mean			
Pair 1	Pre-test/15	5.200	50	2.8212		.3990			
	Post-test/15	9.600	50	3.0506		.4314			
		Paired Differences							
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pre-test/15 Post-test/15	-4.4000	3.4226	.4840	-5.3727	-3.4273	-9.090	49	.000

For the paired-sample t-test, Cohen's d test:

$$d = \frac{4.4}{3.4226} = 1.3,$$

therefore, the effect size is large. The SSKT pre-test and post-test scores of the grade 8 control group differ by 1.3 standard deviations.

Grade 8 Experimental Group

A paired t-test for the experimental group was conducted and results show that the mean for the pre-test is 5.180 and 11.960 for the post-test scores. There was a significant difference in the scores for pre-tests (M=5.180, SD=2.7456) and post-tests (M=11.960, SD= 2.2674) at the 5% and 1% levels of significance ($t(49) = -14.652$, $p < .001$) as illustrated in Table 18. The average difference between the pre-test and post-test mean scores is -6.780. This means that an average student gained a score of 6.780 from the RCD for PBL. Since $p < .001$, we reject the null hypothesis at the 5% and 1% levels of significance. The sample data support the notion that the average paired difference does not equal zero. Specifically, the post-test mean is greater than the pre-test mean. The 95% confidence interval estimates that the actual population difference between the pre-test and post-test is likely to be between -7.7099 and -5.8501. The confidence interval excludes the value of zero thus, the RCD-PBL results in a significant increase in the SSKT scores. For the experimental group, it is observed that the post-test scores are significantly better than the pre-test scores.

Table 18: Statistics and Paired T-Test for Grade 8 Experimental Pre-Test and Post-Test SSKT Scores

		Mean	N	Std. Deviation		Std. Error Mean			
Pair 1	Pre-test/15	5.180	50	2.7456		.3883			
	Post-test/15	11.960	50	2.2674		.3207			
		Paired Differences						df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pre-test/15 Post-test/15	-6.7800	3.2720	.4627	-7.7099	-5.8501	-14.652	49	.000

For the paired-sample t-test, Cohen's d test:

$$d = \frac{6.78}{3.272} = 2.07,$$

therefore, the effect size is large. The SSKT pre-test and post-test scores of grade 8 experimental group differ by 2.07 standard deviations.

Grade 8 Control and Experimental Groups

Comparing the control and experimental groups of Grade 8, the statistical analysis shows that there is a higher mean gain in SSKT scores for the experimental group than the control group. The mean pre-test scores of 5.200 and 5.180 of the control group and the experimental group respectively are almost equal and therefore it is meaningful to compare their post-test scores on SSKT. An average student in the experimental group gained 6.780 points on the SSKT as compared to a student in the control group who gained an average of 4.400 points.

Grades 6, 7, and 8 Control Group

A paired samples t-test was done for all the grades for the control group on the pre-test and post-test SSKT. Paired samples statistics show a mean of 6.621 and a standard deviation of 2.9290 for the pre-test SSKT scores and a mean and standard deviation of 10.320 and 2.6893 for the post-test SSKT scores respectively as illustrated in Table 19.

Table 19: Statistics and Paired T-Test for Grades 6, 7, and 8 Control Pre-Test and Post-Test SSKT Scores

		Mean	N	Std. Deviation		Std. Error Mean			
Pair 1	Pre-test/15	6.621	153	2.9290		.2368			
	Post-test/15	10.320	153	2.6893		.2174			
		Paired Differences						df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pre-test/15 Post-test/15	-3.6993	2.5652	.2074	-4.1091	-3.2896	-17.838	152	.000

Results from the paired samples test show that the mean difference 3.6993 of the post-test and pre-test scores is significantly different from zero ($t(152) = -17.838$, $p < .001$) at the 5% and 1% levels of statistical significance. Therefore, for all grades combined, the mean difference between the post-test and pre-test SSKT scores for the control group is greater than zero.

For the paired-sample t-test, Cohen's d test:

$$d = \frac{3.6993}{2.5652} = 1.44,$$

therefore, the effect size is large. The SSKT pre-test and post-test scores of the middle school learners (grades 6, 7, and Grade 8 combined) control group differ by 1.44 standard deviations.

Grades 6, 7, and 8 Experimental Group

A paired samples t-test was done for all the grades for the experimental group on the pre-test and post-test SSKT as shown in Table 8. Paired samples statistics show a mean of 6.662 and a standard deviation of 2.7077 for the pre-test SSKT scores and a mean and standard deviation of 12.172 and 2.0905 for the post-test SSKT scores respectively as observed in Table 20.

Table 20: Statistics and Paired T-Test for Grades 6, 7, and 8 Experimental Pre-Test and Post-Test SSKT Scores

		Mean	N	Std. Deviation		Std. Error Mean			
Pair 1	Pre-test/15	6.662	151	2.7077		0.2204			
	Post-test/15	12.172	151	2.0905		0.1701			
		Paired Differences						df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pre-test/15 Post-test/15	-5.5099	2.5997	0.2116	-5.9280	-5.0919	-26.045	150	0.001

Results from the paired samples test show that the mean difference (5.5099) of the post-test and pre-test is significantly different from zero ($t(150) = -26.045$, $p < .001$) at the 5 % and 1 % levels of statistical significance. Therefore, for all grades combined, the mean difference between the post-test and pre-test SSKT scores for the experimental group is greater than zero. The mean difference of the experimental group (5.5099) is higher than the mean difference for the control group (3.6993) for post-test and pre-test SSKT scores by 1.8106 points.

For the paired-sample t-test, Cohen's d test:

$$d = \frac{5.5099}{2.5997} = 2.12,$$

therefore, the effect size is large. The SSKT pre-test and post-test scores of the middle school learners (grades 6, 7, and 8 combined) experimental group differ by 2.12 standard deviations.

Paired Sample T-test for each Grade Level by Gender

The SPSS analysis output for the analysis of the paired sample t-test for each grade level by gender is shown in Appendix H. A summary of the paired sample t-test for the pre-test and post-test mean difference in SSKT scores for each grade is shown in Table 21.

Table 21: Paired Difference of Pre-Test and Post-Test Mean SSKT Scores

	Control female	Control male	Experimental female	Experimental male
Grade 6	2.7692 ($p < .001$)	2.9600 ($p < .001$)	5.0000 ($p < .001$)	4.6000 ($p < .001$)
Grade 7	3.4815 ($p < .001$)	4.2400 ($p < .001$)	4.8800 ($p < .001$)	5.0400 ($p < .001$)
Grade 8	2.6400 ($p < .001$)	6.1600 ($p < .001$)	4.8400 ($p < .001$)	8.7200 ($p < .001$)

Results from the paired sample t-test for the control female, control male, experimental female, and experimental male groups for all grades show that the mean difference of the post-test and pre-test scores are significantly different from zero ($p < .001$) at the 5% level of statistical significance. Therefore, for all grades, groups, and genders, the mean difference between the post-test and pre-test SSKT scores is greater than zero. From the paired differences results shown in Table 12, it can be seen that the largest paired difference for the post-test and pre-test SSKT scores are 5.00, 5.04, and 8.7200 for the grade 6 experimental female, grade 7 experimental male, and grade 8 experimental male respectively. This shows that the female experimental science students in grade 6 had the most achievement in the SSKT scores. Results also show that the grade 7 and grade 8 experimental male groups had the highest achievement in the pre-post-test SSKT scores. These results show that female students are also capable of higher achievement in SSKT scores than their male counterparts. Results show that the male control group outperformed the female control groups in achievement in the SSKT scores for grades 6, 7, and 8. The experimental female and experimental male groups had higher paired differences in the pre-test and post-test SSKT scores than their corresponding students in the control female and control male groups respectively. RCD for PBL, therefore, has a positive impact on the achievement in SSKT scores for grades 6, 7, and 8 science students in Abu Dhabi, UAE. Based on these results it can be concluded that rigorous curriculum design for project-based learning implementation affect middle school students' achievement in science standardized knowledge tests, in Abu Dhabi, UAE.

4.2.2.2 SSKT Achievement Improvement: Independent Sample T-test and ANOVA

An independent sample t-test was performed to analyze the variable improvement which is equal to the post-test minus the pre-test SSKT scores for grades 6, 7, and 8 separately and all grades combined. The variable improvement is analyzed for the control and experimental groups.

The null and alternative hypotheses for the independent sample t-test for the improvement are:

- $H_0: \mu_1 = \mu_2$, There is no statistical significant difference in the mean improvement in SSKT scores between, RCD project-based learning (experimental group) versus textbook curriculum (control group).

- $H_a : \mu_1 \neq \mu_2$, There is a statistical significant difference in the mean improvement in SSKT scores between, RCD project-based learning (experimental group) versus textbook curriculum (control group).

where μ_1 and μ_2 are the mean of the control group and the experimental group SSKT scores respectively.

Grades 6, 7, and 8 SSKT Improvement

An independent samples t-test is performed for all grades on the dependent variable improvement using the independent variables, control, and experimental. Descriptive statistics in Table 13 show that for the control (N=153) an average student has a mean improvement of 3.70 points with a standard deviation of 2.565 on the improvement in the SSKT. The experimental group (N=151) had a mean improvement of 5.51 points for the average student, with a standard deviation of 2.600 on the improvement in the SSKT as observed in Table 22. The experimental group has a higher mean improvement than the control group by 1.811 points.

Table 22: Group Statistics and Independent T-Test for Grades 6, 7, and 8 SSKT Improvement

		Group	N	Mean		Std. Deviation		Std. Error Mean		
Improvement		Control	153	3.70		2.565		.207		
		Experimental	151	5.51		2.600		.212		
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Improvement	Equal variances assumed	.000	.993	-6.112	302	.000	-1.811	.296	-2.394	-1.228
	Equal variances not assumed			-6.112	301.787	.000	-1.811	.296	-2.394	-1.228

The F-test is used in Levene's test to evaluate the null hypothesis that the variance for the control and the experimental groups for the middle school grade levels (grades 6, 7, and 8

combined) is equal. A p-value of less than .05 shows that the assumption has been violated. If a violation occurs, a non-parametric equivalent of the analysis is more appropriate. Levene's test for equality of variances shows a p-value = 0.993 > 0.05, therefore the assumption of homogeneity of variance for the control and experimental groups is met. Independent t-test results show that there is a significant difference ($t(302) = -6.112, p < .001$) in the improvement in the SSKT between the grade 6,7, and 8 control and experimental groups at the 5% and 1% level of significance. Therefore, we can conclude that RCD for PBL significantly improved the scores of grades 6, 7, and 8 students in the SSKT, at the 5% and 1% levels of statistical significance. Cohen's d-test for the independent samples t-test is,

$$d = \frac{\bar{x} - \bar{y}}{\sqrt{\frac{(n_1 - 1)S_1^2 + (n_2 - 1)S_2^2}{n_1 + n_2 - 2}}}$$

$$d = \frac{5.51 - 3.70}{\sqrt{\frac{(151 - 1)2.6^2 + (153 - 1)2.565^2}{151 + 153 - 2}}} = 0.7.$$

The relative size of the difference between the mean of the experimental and control groups is medium and therefore statistically significant in the real world. An effect size of 0.7 means that the score of the average student in the experimental group in the improvement in science standardized knowledge test is 0.7 standard deviations higher than the average student in the control group, and hence exceeds the scores of 76% of the control group of students that did not receive the RCD-PBL (Saul McLeod 2019) in middle school students, in Abu Dhabi, UAE.

Grade 6 SSKT Improvement

For the control group (N=51), there was a mean improvement of 2.86 points for the average student, with a standard deviation of 1.386 on the improvement in the SSKT (Table 23). The experimental group (N=51) had a mean improvement of 4.80 points for the average student, with a standard deviation of 1.778 on the improvement in the SSKT. The experimental group has a higher mean improvement than the control group by 1.94 points.

Table 23: Group Statistics and Independent T-Test for Grade 6 SSKT Improvement

		Group	N	Mean		Std. Deviation		Std. Error Mean		
Improvement		Control	51	2.86		1.386		.194		
		Experimental	51	4.80		1.778		.249		
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Improvement	Equal variances assumed	1.842	.178	-6.150	100	.000	-1.941	.316	-2.567	-1.315
	Equal variances not assumed			-6.150	94.380	.000	-1.941	.316	-2.568	-1.314

Levene's test for equality of variances shows a p-value = 0.178 > 0.05, therefore the assumption of homogeneity of variance for the control and experimental groups is satisfied. Independent t-test results show that there is a significant difference ($t(100) = -6.150$, $p < .001$) in the improvement in the SSKT between the grade 6 control and experimental groups at the 5% and 1% level of significance. Therefore, we can conclude that RCD for PBL significantly improved the scores of grade 6 students in the SSKT, at the 5% and 1% levels of statistical significance. Using the group statistics and independent test statistics Cohen's d statistic is,

$$d = \frac{4.80 - 2.86}{\sqrt{\frac{(51 - 1)1.778^2 + (51 - 1)1.386^2}{51 + 51 - 2}}} = 1.2,$$

The relative size of the difference between the mean of the experimental and control groups is large and therefore statistically significant. An effect size of 1.2 means that the score of the average student in the experimental group in the improvement in the science standardized knowledge test is 1.2 standard deviations higher than the average student in the control group, and hence exceeds the scores of 88.6% (Saul McLeod 2019) of the control group of students that did not receive the RCD-PBL in grade 6 students, in Abu Dhabi, UAE.

Grade 7 SSKT Improvement

For the control group (N=52), there was a mean improvement of 3.85 points for the average student, with a standard deviation of 2.296 on the improvement in the SSKT (Table 24). The experimental group (N=50) had a mean improvement of 4.96 points for the average student, with a standard deviation of 2.070 on the improvement in the SSKT. The experimental group has a higher mean improvement than the control group by 1.11 points.

Table 24: Group Statistics and Independent T-Test for Grade 7 SSKT Improvement

		Group	N	Mean	Std. Deviation	Std. Error Mean				
Improvement	Control	52		3.85	2.296	.318				
	Experimental	50		4.96	2.070	.293				
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Improvement	Equal variances assumed	1.709	.194	-2.570	100	.012	-1.114	.433	-1.974	-.254
	Equal variances not assumed			-2.576	99.595	.011	-1.114	.432	-1.972	-.256

Levene's test for equality of variances shows a p-value = 0.194 > 0.05, therefore the assumption of homogeneity of variance for the control and experimental groups is satisfied. Independent t-test results show that there is a significant difference ($t(100) = -2.57$, $p < .012$) in the improvement in the SSKT between the grade 7 control and experimental groups at the 5% level of significance. Therefore, we can conclude that RCD for PBL significantly improved the scores of grade 7 students in the SSKT, at the 5% level of statistical significance. Cohen's d statistic is,

$$d = \frac{4.96 - 3.85}{\sqrt{\frac{(50 - 1)2.070^2 + (52 - 1)2.296^2}{50 + 52 - 2}}} = 0.51,$$

The relative size of the difference between the mean of the experimental and control groups is medium and therefore statistically significant. An effect size of 0.51 means that the score of the average student in the experimental group in the improvement in the science standardized knowledge test is 0.51 standard deviations higher than the average student in the control group, and hence exceeds the scores of 69% (Saul McLeod 2019) of the control group of students that did not receive the RCD-PBL in grade 7 students, in Abu Dhabi, UAE.

Grade 8 SSKT Improvement

For the control group (N=50), there was a mean improvement of 4.40 points for the average student, with a standard deviation of 3.423 on the improvement in the SSKT (Table 25). The experimental group (N=50) had a mean improvement of 6.78 points for the average student, with a standard deviation of 3.272 on the improvement in the SSKT. The experimental group has a higher mean improvement than the control group by 2.38 points.

Table 25: Group Statistics and Independent T-Test for Grade 8 SSKT Improvement

		Group	N	Mean	Std. Deviation	Std. Error Mean				
Improvement		Control	50	4.40	3.423	.484				
		Experimental	50	6.78	3.272	.463				
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Improvement	Equal variances assumed	.001	.975	-3.554	98	.001	-2.380	.670	-3.709	-1.051
	Equal variances not assumed			-3.554	97.802	.001	-2.380	.670	-3.709	-1.051

Levene's test for equality of variances shows a p-value = 0.975 > 0.05, therefore the assumption of homogeneity of variance for the control and experimental groups is satisfied. Independent t-test results show that there is a significant difference ($t(98) = -3.554$, $p < .001$) in the improvement in the SSKT between the grade 8 control and experimental groups at the 5% and 1% level of significance. Therefore, we can conclude that RCD for PBL significantly

improved the scores of grade 8 students in the SSKT, at the 5% and 1% levels of statistical significance.

Cohen's d statistic is,

$$d = \frac{6.78 - 4.40}{\sqrt{\frac{(50 - 1)3.272^2 + (50 - 1)3.423^2}{50 + 50 - 2}}} = 0.71,$$

The relative size of the difference between the mean of the experimental and control groups is medium and therefore statistically significant. An effect size of 0.71 means that the score of the average student in the experimental group in the improvement in the science standardized knowledge test is 0.71 standard deviations higher than the average student in the control group, and hence exceeds the scores of 76% (Saul McLeod 2019) of the control group of students that did not receive the RCD-PBL in Grade 8 students, in Abu Dhabi, UAE.

One-Way Analysis of Variance of the Improvement in SSKT Scores

Since we found significant differences in the improvement in the SSKT scores between the experimental and control groups for all grades combined (grades 6, 7, and 8), we perform a one-way analysis of variance in order to determine which grades have statistically significant differences. The null and alternative hypotheses for the one-way ANOVA for the improvement are:

- $H_0: \mu_1 = \mu_2 = \mu_3$, There is no statistical significant difference between the SSKT mean improvement scores for grade 6, grade 7, and grade 8.
- $H_a: \mu_i \neq \mu_j$, for some $i \neq j$, There is a statistical significant difference between the SSKT mean improvement scores for grade 6, grade 7, and grade 8.

where μ_1, μ_2, μ_3 are the mean of the improvement in the SSKT scores for grade 6, grade 7, and grade 8 respectively.

ANOVA of the Improvement for Grades 6, 7, and 8

Descriptive statistics in Table 26 show the mean improvement of Grade 6 (M=3.83, SD=1.862), Grade 7 (M=4.39, SD=2.248), and Grade 8 (M=5.59, SD=3.539) groups. It is noted that when the ANOVA test is conducted, the homogeneity of variances assumption needs to be satisfied. Therefore, Levene's test is performed.

Table 26: Group Statistics for Grades 6,7, and 8 SSKT Improvement

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Grade6	102	3.83	1.862	.184	3.47	4.20	0	9
Grade7	102	4.39	2.248	.223	3.95	4.83	-1	12
Grade8	100	5.59	3.539	.354	4.89	6.29	0	13
Total	304	4.60	2.733	.157	4.29	4.91	-1	13

A p-value < .05 from Levene's test (Table 27) shows that the assumption of homogeneity of variances is violated.

Table 27: Homogeneity Test of Variance for Grades 6,7, and 8 SSKT Improvement

Levene Statistic	df1	df2	Sig.
28.398	2	301	.000

One-way ANOVA results show that there are significant ($p < .001$) differences between the mean improvement in SSKT scores for grade 6, grade 7, and grade 8 at the 5% level of statistical significance (Table 28).

Table 28: ANOVA of Grades 6,7, and 8 SSKT Improvement

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	162.369	2	81.185	11.633	.000
Within Groups	2100.670	301	6.979		
Total	2263.039	303			

Since the assumption of homogeneity of variances is violated, we use the Welch robust test of equality of means. The Welch test does not assume the homogeneity of variances assumption. Results from the Welch test ($p < .001$), show that there is a significant difference in the mean improvement in SSKT scores for grade 6, grade 7, and grade 8 at the 5% level of statistical significance (Table 29).

Table 29: Robust Tests of Equality of Means Grades 6,7, and 8 SSKT Improvement

	Statistic ^a	df1	df2	Sig.
Welch	9.875	2	189.932	.000

a. Asymptotically F distributed.

To find out which group means are different among the middle school grade levels and therefore, significant, a post-hoc test such as Fisher's least significance difference (LSD) is performed. LSD was chosen as a post-hoc test as the sample size in each grade is equal or similar and had not more than three levels in the independent variable (grade). The LSD results show that there is no significant difference in mean improvement in SSKT between grade 6 and grade 7, but there are significant differences between grade 8 and grade 7, grade 8 and grade 6 at the 5% level of statistical significance (Table 30).

Table 30: LSD Multiple Comparisons of Means of Grade 6,7 and 8 SSKT Improvement

(I) Grade	(J) Grade	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Grade6	Grade7	-.559	.370	.132	-1.29	.17
	Grade8	-1.757*	.372	.000	-2.49	-1.03
Grade7	Grade6	.559	.370	.132	-.17	1.29
	Grade8	-1.198*	.372	.001	-1.93	-.47
Grade8	Grade6	1.757*	.372	.000	1.03	2.49
	Grade7	1.198*	.372	.001	.47	1.93

*. The mean difference is significant at the 0.05 level.

A plot of the mean improvement (Figure 7) shows that there is a linear increase in the mean improvement in SSKT scores from grade 6 to grade 8.

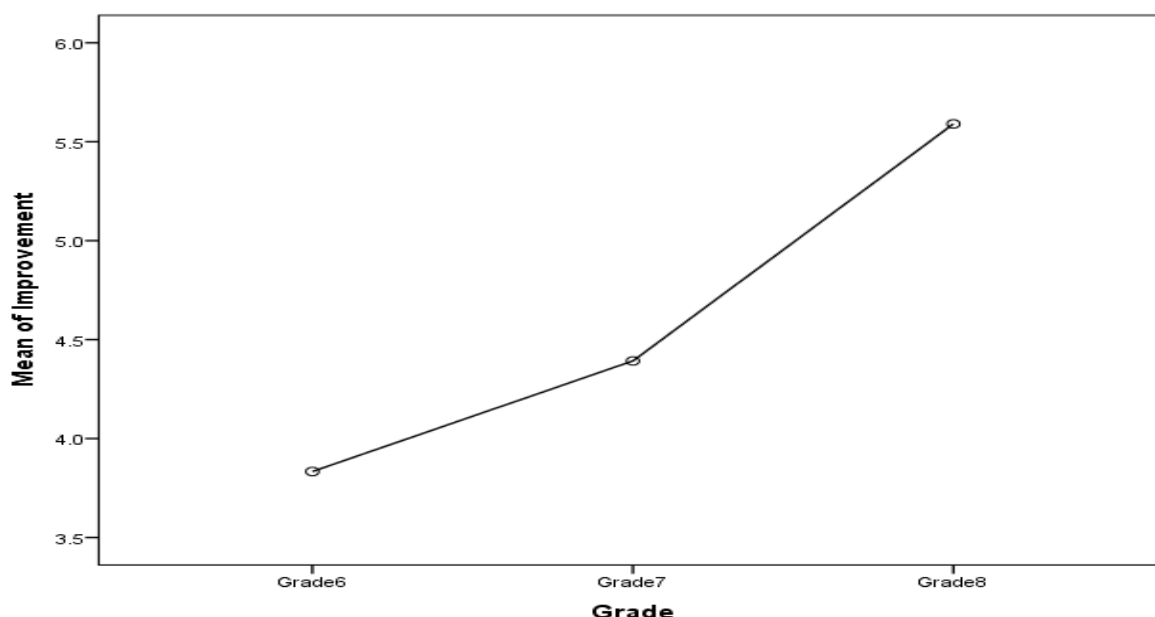


Figure 7: Mean Improvement for Grades 6, 7, and 8

Two-way ANOVA of SSKT Improvement for Grades and Groups

Since a significant difference was found in the mean improvement in the SSKT scores between the grades and between experimental and control groups for all grade levels, a two-way ANOVA was used to compare the mean SSKT improvement differences between grade and group. The primary purpose of the two-way ANOVA was to understand if there was an interaction between the independent variables, grade levels, and group on the dependent variable, mean SSKT improvement. A two-way ANOVA was done for grades (6, 7, and 8) with groups (control female, control male, experimental female, and experimental male), to determine the effect of grade and group and their interaction on the SSKT mean improvement.

Descriptive statistics in Table 22 show that the mean improvement for grade 6, the control female (mean=2.77, standard deviation=1.243), control male (mean=2.96, standard deviation=1.541), experimental female (mean=5.00, standard deviation=1.960) and experimental male (mean=4.60, standard deviation=1.581) groups. The mean improvement of the control groups for all grade levels is less than the mean improvement of the experimental groups with the highest improvement SSKT mean improvement for experimental female in grade 6 (M=5.00, SD=1.960) and experimental male respectively in grade 7 (M=5.04, SD=2.131) and grade 8 (M=8.72, SD=2.951) as shown in Table 31.

Table 31: Descriptive Statistics for Grades 6,7, and 8 SSKT Mean Improvement with Group and Gender

Descriptive Statistics				
Dependent Variable: Improvement				
Grades	Group and gender	Mean	Std. Deviation	N
Grade 6	Control female	2.77	1.243	26
	Control male	2.96	1.541	25
	Experimental female	5.00	1.960	26
	Experimental male	4.60	1.581	25
	Total	3.83	1.862	102
Grade 7	Control female	3.48	1.649	27
	Control male	4.24	2.818	25
	Experimental female	4.88	2.048	25
	Experimental male	5.04	2.131	25
	Total	4.39	2.248	102
Grade 8	Control female	2.64	1.411	25
	Control male	6.16	3.934	25
	Experimental female	4.84	2.304	25
	Experimental male	8.72	2.951	25
	Total	5.59	3.539	100
Total	Control female	2.97	1.477	78
	Control male	4.45	3.181	75
	Experimental female	4.91	2.080	76
	Experimental male	6.12	2.927	75
	Total	4.60	2.733	304

Analysis results in Table 32 show statistical significant ($p < .05$) differences in the mean SSKT improvement for the variables grade and group/gender. There was a significant interaction between the grade level and group*gender on the SSKT mean improvement, $F(6, 292)=7.830$, $p<0.001$.

Table 32: Descriptive Statistics for Grades 6,7, and 8 SSKT Mean Improvement with Group and Gender

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	785.043 ^a	11	71.368	14.100	0.000	.347
Intercept	6459.378	1	6459.378	1276.146	0.000	.814
Grade	161.758	2	80.879	15.979	0.000	.099
Groupandgender	390.704	3	130.235	25.730	0.000	.209
Grade * Groupandgender	237.794	6	39.632	7.830	0.000	.139
Error	1477.996	292	5.062			
Total	8692.000	304				
Corrected Total	2263.039	303				
a. R Squared = 0.347 (Adjusted R Squared = 0.322)						

Table 33: Tukey Honestly Significant Difference (HSD) Multiple Comparisons of the Mean of Grade levels on SSKT Mean Improvement

Multiple Comparisons						
Dependent Variable: Improvement						
Tukey HSD						
(I) Grade	(J) Grade	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Grade 6	Grade 7	-.56	.315	.180	-1.30	.18
	Grade 8	-1.76*	.317	.000	-2.50	-1.01
Grade 7	Grade 6	.56	.315	.180	-.18	1.30
	Grade 8	-1.20*	.317	.001	-1.94	-.45
Grade 8	Grade 6	1.76*	.317	.000	1.01	2.50
	Grade 7	1.20*	.317	.001	.45	1.94
Based on observed means.						
The error term is Mean Square(Error) = 5.062.						
*. The mean difference is significant at the .05 level.						

Table 34: Tukey Honestly Significant Difference (HSD) Multiple Comparisons of the Mean of Group and Gender on SSKT Mean Improvement

Multiple Comparisons						
Dependent Variable: Improvement						
Tukey HSD						
(I) Group and gender	(J) Group and gender	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	95% Confidence Interval
					Lower Bound	Upper Bound
Control female	Control male	-1.48*	.364	.000	-2.42	-.54
	Experimental female	-1.93*	.363	.000	-2.87	-1.00
	Experimental male	-3.15*	.364	.000	-4.09	-2.21
Control male	Control female	1.48*	.364	.000	.54	2.42
	Experimental female	-.45	.366	.601	-1.40	.49
	Experimental male	-1.67*	.367	.000	-2.62	-.72
Experimental female	Control female	1.93*	.363	.000	1.00	2.87
	Control male	.45	.366	.601	-.49	1.40
	Experimental male	-1.21*	.366	.006	-2.16	-.27
Experimental male	Control female	3.15*	.364	.000	2.21	4.09
	Control male	1.67*	.367	.000	.72	2.62
	Experimental female	1.21*	.366	.006	.27	2.16

Turkey HSD results in Table 33 and 34 respectively show that there are a statistically significant ($p < .05$) differences in mean SSKT improvement between grade 6 and 8 ($MD = -1.76$), and grade 7 and 8 ($MD = -1.20$). Moreover, a statistically significant ($p < .05$) differences were found between the groups, control female and experimental female ($MD = -1.93$), control male and experimental male ($MD = -1.67$), control female and control male ($MD = -1.48$), control female and experimental male ($MD = -3.15$), experimental male and experimental female ($MD = -1.21$). These significant differences in the mean SSKT improvement for control females and control males, and experimental males and experimental females clearly show that gender also plays a significant role in the mean SSKT improvement.

As there is a statistical significance interaction between the grade and group*gender on the SSKT mean improvement, a simple main effect was performed to analyze the degree to which the first independent variable is differentially effective at each level of our second independent variable. Thus, analyzing the effect of group*gender (RCD-PBL vs Non-PBL) changes depending on the student grade level as shown in Table 35 was carried out.

Looking at the pairwise comparisons, the below can be concluded:

- For grade 6, the experimental groups (RCD-PBL implementation) for both genders led to higher SSKT mean improvement than the control groups (non-PBL, textbook curriculum implementation) ($p < .05$). While no significant effect exists between experimental groups, experimental female outperformed the experimental male.
- for grade 7, the experimental groups for both genders led to higher SSKT mean improvement in comparison with control females ($p < .05$). While no significant effect exists with the control male group or between experimental groups, the experimental male outperformed the rest.
- For grade 8, experimental male led to higher SSKT mean improvement in comparison with experimental female or with any other control groups whether males or females ($p < .05$). In addition, a significant effect exists between all groups whether experimental or control.

Table 35: Main Effect of Grades on SSKT Mean Improvement

Pairwise Comparisons							
Dependent Variable: Improvement							
Grades	(I) Group and gender	(J) Group and gender	Mean Difference (I-J)	Std. Error	Sig. ^b	95% Confidence Interval for Difference ^b	
						Lower Bound	Upper Bound
Grade 6	Control female	Control male	-.191	.630	.762	-1.431	1.050
		Experimental female	-2.231*	.624	.000	-3.459	-1.003
		Experimental male	-1.831*	.630	.004	-3.071	-.590
	Control male	Control female	.191	.630	.762	-1.050	1.431
		Experimental female	-2.040*	.630	.001	-3.280	-.800
		Experimental male	-1.640*	.636	.010	-2.892	-.388
	Experimental female	Control female	2.231*	.624	.000	1.003	3.459
		Control male	2.040*	.630	.001	.800	3.280
		Experimental male	.400	.630	.526	-.840	1.640
	Experimental male	Control female	1.831*	.630	.004	.590	3.071
		Control male	1.640*	.636	.010	.388	2.892
		Experimental female	-.400	.630	.526	-1.640	.840
Grade 7	Control female	Control male	-.759	.624	.225	-1.988	.470
		Experimental female	-1.399*	.624	.026	-2.628	-.170
		Experimental male	-1.559*	.624	.013	-2.788	-.330
	Control male	Control female	.759	.624	.225	-.470	1.988
		Experimental female	-.640	.636	.315	-1.892	.612
		Experimental male	-.800	.636	.210	-2.052	.452
	Experimental female	Control female	1.399*	.624	.026	.170	2.628
		Control male	.640	.636	.315	-.612	1.892
		Experimental male	-.160	.636	.802	-1.412	1.092
	Experimental male	Control female	1.559*	.624	.013	.330	2.788
		Control male	.800	.636	.210	-.452	2.052
		Experimental female	.160	.636	.802	-1.092	1.412
Grade 8	Control female	Control male	-3.520*	.636	.000	-4.772	-2.268
		Experimental female	-2.200*	.636	.001	-3.452	-.948
		Experimental male	-6.080*	.636	.000	-7.332	-4.828
	Control male	Control female	3.520*	.636	.000	2.268	4.772
		Experimental female	1.320*	.636	.039	.068	2.572
		Experimental male	-2.560*	.636	.000	-3.812	-1.308
	Experimental female	Control female	2.200*	.636	.001	.948	3.452
		Control male	-1.320*	.636	.039	-2.572	-.068

		Experimental male	-3.880*	.636	.000	-5.132	-2.628
	Experimental male	Control female	6.080*	.636	.000	4.828	7.332
		Control male	2.560*	.636	.000	1.308	3.812
		Experimental female	3.880*	.636	.000	2.628	5.132
Based on estimated marginal means							
*. The mean difference is significant at the .05 level.							
b.Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).							

It has been confirmed that RCD-PBL has a significant impact in grades 6 and 8 and grades 7 and 8 ($p < .05$) as shown previously in the post hoc test, more specifically for experimental males as shown in Table 36.

Table 36: The Main Effect of Group and Gender on SSKT Mean Improvement

Pairwise Comparisons							
Dependent Variable: Improvement							
Group and gender	(I) Grade	(J) Grade	Mean Difference (I-J)	Std. Error	Sig. ^b	95% Confidence Interval for Difference ^b	95% Confidence Interval for Difference
						Lower Bound	Upper Bound
Control female	Grade6	Grade7	-.712	.618	.250	-1.929	.504
		Grade8	.129	.630	.838	-1.111	1.370
	Grade7	Grade6	.712	.618	.250	-.504	1.929
		Grade8	.841	.624	.179	-.388	2.070
	Grade8	Grade6	-.129	.630	.838	-1.370	1.111
		Grade7	-.841	.624	.179	-2.070	.388
Control male	Grade6	Grade7	-1.280*	.636	.045	-2.532	-.028
		Grade8	-3.200*	.636	.000	-4.452	-1.948
	Grade7	Grade6	1.280*	.636	.045	.028	2.532
		Grade8	-1.920*	.636	.003	-3.172	-.668
	Grade8	Grade6	3.200*	.636	.000	1.948	4.452
		Grade7	1.920*	.636	.003	.668	3.172
Experimental female	Grade6	Grade7	.120	.630	.849	-1.120	1.360
		Grade8	.160	.630	.800	-1.080	1.400
	Grade7	Grade6	-.120	.630	.849	-1.360	1.120
		Grade8	.040	.636	.950	-1.212	1.292
	Grade8	Grade6	-.160	.630	.800	-1.400	1.080
		Grade7	-.040	.636	.950	-1.292	1.212
Experimental male	Grade6	Grade7	-.440	.636	.490	-1.692	.812
		Grade8	-4.120*	.636	.000	-5.372	-2.868
	Grade7	Grade6	.440	.636	.490	-.812	1.692
		Grade8	-3.680*	.636	.000	-4.932	-2.428
	Grade8	Grade6	4.120*	.636	.000	2.868	5.372
		Grade7	3.680*	.636	.000	2.428	4.932

4.2.2.3 Summary of RQ1 Quantitative Results

For RQ1, in order to determine if there is a statistical significant difference between Pre-Posttest SSKT scores in science, paired samples t-test was performed and a summary of the results was represented in Table 37 whereby the results showed that:

- The difference between the post-test and pre-test mean SSKT scores is significant for the control and experimental groups of grade 6, grade 7, and grade 8.
- All students in the experimental groups of grades 6, 7, and 8 showed improvement in the SSKT and outperformed their corresponding control groups.
- An average student in grade 6 in the experimental group gained 4.8039 points on the SSKT compared to a student in the control group who gained an average of 2.8627.
- An average student in grade 7 in the experimental group gained 4.9600 points on the SSKT compared to a student in the control group who gained an average of 3.8462.
- An average student in grade 8 in the experimental group gained 6.780 points on the SSKT compared to a student in the control group who gained an average of 4.400 points.

Table 37: Summary of Paired Samples T-Test in SSKT Scores in Science for Grades 6,7, and 8

Grade Levels	Pre-test		Post-test							
	Mean	SD	Mean	SD	Mean paired Difference	SD	t	df	Sig.	Effect size
Grade 6 control	7.725	2.892	10.588	2.451	-2.8627	1.386	-14.751	50	< 0.0001	2.07
Grade 6 experimental	7.745	2.440	12.549	1.973	-4.804	1.778	-19.297	50	< 0.0001	2.70
Grade 7 control	6.904	2.538	10.750	2.441	-3.846	2.296	-12.082	51	< 0.0001	1.68
Grade 7 experimental	7.040	2.285	12.000	2.010	-4.960	2.070	-16.945	49	< 0.0001	2.40
Grade 8 control	5.200	2.821	9.600	3.051	-4.400	3.423	-9.090	49	< 0.0001	1.30
Grade 8 experimental	5.180	2.746	11.960	2.267	-6.780	3.272	-14.652	49	< 0.0001	2.07

In the analysis of pre-test and post-test paired sample t-test SSKT scores by gender, results showed that:

- The control female, control male, experimental female, and experimental male groups had significant ($p < .001$) gains in achievement in the SSKT scores in grades 6, 7, and 8.

- The RCD-PBL science students gained more on average in the SSKT scores than the non-PBL students for grades 6, 7, and 8 for both genders.
- A non-PBL male on average gained more than the respective non-PBL female for grades 6, 7, and 8 in the pre-test to post-test SSKT scores.
- A PBL female student gained more on average than a male PBL student in grade 6, whereas a PBL male science student for grade 7 and grade 8 gained more than the corresponding female student in those respective grades.

These results show that gender might be playing a role in achievement in the SSKT scores.

With regards to the improvement in SSKT scores, the independent samples t-test conducted showed that there are statistically significant differences ($p < .05$) between the non-PBL (traditional textbook curriculum) and PBL (RCD-PBL curriculum) groups in SSKT scores on science assessment of middle school students from private schools in Abu Dhabi, UAE. The results from quantitative analysis summarized in Table 38 show that the score of the average student in the experimental group in Abu Dhabi, UAE is:

- 0.70 standard deviations higher than the average student in the control group, and hence exceeds the scores of 76% of the control group of students that did not receive the RCD-PBL (Saul McLeod 2019) in middle school (grades 6, 7, and 8 combined).
- 1.2 standard deviations higher than the average student in the control group, and hence exceeds the scores of 88.6% of the control group of students that did not receive the RCD-PBL in grade 6.
- 0.51 standard deviations higher than the average student in the control group, and hence exceeds the scores of 69% of the control group of students that did not receive the RCD-PBL in grade 7.
- 0.71 standard deviations higher than the average student in the control group, and hence exceeds the scores of 76% of the control group of students that did not receive the RCD-PBL in grade 8.

Table 38: Summary of Mean Students Improvement in SSKT Scores

Grade Levels	Non-PBL		PBL						
	Mean	SD	Mean	SD	Mean Difference	t	df	Sig.	Effect size
Grades 6, 7, and 8 combined	3.70	2.565	5.51	2.600	-1.811	-6.112	302	< 0.0001	0.70
Grade 6	2.86	1.386	4.80	1.778	-1.941	-6.150	100	< 0.0001	1.2
Grade 7	3.85	2.296	4.96	2.070	-1.114	-2.570	100	< 0.012	0.51
Grade 8	4.40	3.423	6.78	3.272	-2.380	-3.554	98	< 0.001	0.71

One-way ANOVA results in Table 39 showed that there are statistically significant differences ($p < .05$) between the non-PBL and RCD-PBL groups in the mean of middle students' improvement SSKT scores in science assessment in a private school in Abu Dhabi, UAE. Through an LSD post hoc test, it has been confirmed that RCD-PBL has a significant impact between grades 6 and 8 and grades 7 and 8 ($p < .05$). Therefore, to determine the effect of grade and group and their interaction on the SSKT mean improvement a two-way ANOVA was conducted, whereby the results of the test, Tukey HSD post-hoc multiple comparison test, and simple main effect showed:

- That RCD-PBL has a significant impact between grades 6 and 8 and grades 7 and 8 ($p < .05$) more specifically for the experimental male group.
- For grade 6, while experimental groups outperformed the control groups, more specifically experimental females compared to experimental males, no significant effect was found between gender in the experimental groups.
- For grade 7, While the experimental male outperformed the rest of the groups, no significant effect exists between the gender in the experimental groups or with the control male.
- For grade 8, while the experimental male outperformed all the rest of the groups, a significant effect exists between all groups whether experimental or control.

Table 39: Summary of One-Way ANOVA on Mean Students Improvement in SSKT scores

Grade Levels	Measure	SSKT scores in Science				
		SS	df	MS	F	Sig.
Grades 6, 7, and 8 combined	Between groups	162.369	2	81.185	11.633	0.000
	Within groups	2100.670	301	6.979		
	Total	2263.039	303			

Finally, the results of the independent samples t-test of the improvement, the paired samples t-test of the pre-test and post-test scores of the SSKT, and ANOVA tests showed that RCD for PBL implementation does affect middle school students' achievement in science standardized knowledge test, in Abu Dhabi, UAE.

4.2.3 Results of Middle School Science MAP Exams Scores

In this section, to determine if there was a significant difference between students' MAP exams results when exposed to RCD-PBL (experimental group) versus textbook-based curriculum, non-PBL based approach (control group), NWEA MAP assessments growth scores were conducted and quantitatively analyzed for the science subject. These assessments, which report individual student results on a continuous scale, were administered at the beginning (Fall 2021) and at the end (Spring 2022) of the school academic year. This period signifies a complete academic year where teachers implemented four RCD-PBL curriculum units.

Students' progress results were collected from the RIT scores of the MAP exams whereby each score can indicate the level of students' understanding, knowledge, and skills. The collected information can help in deciding the level of students' progress in the MAP exam of Spring 2022. This information helps in measuring and evaluating to what extent the implementation of the RCD-PBL has affected students' knowledge and skills and impacted their MAP scores, and whether the student met the target of the projection growth or not. The calculation of each student's growth score in science was done by subtracting his Fall-to-Spring score on these assessments. Only students with valid MAP scores data (students that sat for both exams) were considered in this analysis (N=295). Since these assessments are administered in more than thousands of schools across all countries, the test developers compiled normative data for all test takers, and based on this data, individual growth targets for each student were

established. The science growth target for students compromises the scale score that students starting at a similar level tend to improve on their individual MAP scores from Fall to Spring. Therefore, to answer RQ2, to what extent does rigorous curriculum design for project-based learning implementation affect middle school science students' MAP scores in Abu Dhabi, UAE? descriptive analysis and inferential statistics were performed. For Descriptive analysis, the students' results were classified and analyzed into four categories; the first one (Met growth) indicates that the student attained the projected growth. The second category (Improved) indicated that the student attained a better score in the MAP exam of Spring 2022 but did not meet the projected growth. The third category (Same level) student did not make any progress and stayed at the same level with the same score for the MAP of Fall 2021; neither improved nor declined. Finally, (Declined) indicates that the student gained a lower score in spring 2022 compared with his/her score in fall 2021. Furthermore, an independent sample t-test and ANOVA tests were used to further address the second research question as these results and analysis can be used as strong evidence to determine the effect of using RCD-PBL on students' results in the MAP science exams for the current study.

4.2.3.1 MAP Exams Achievement Growth Scores Descriptive Analysis

Looking at the projected RIT scores and the MET projected growth section from the Achievement Status Growth projection report (ASG) generated from NWEA, all data were color-coded in excel based on the four categories defined earlier: Met growth, Improved, Same level, and Declined. The provided results include percentages of the student's progress and achievement of growth targets in the science MAP exams for each grade level. These results will serve as strong evidence for investigating the effect of RCD-PBL on the MAP scores in science for the current study. The following figures illustrate the results of grades six, seven, and eight science students in the science MAP exam from Fall 2021 to Spring 2022 across two campuses.

Figure 8 represents the grade 6 students with valid MAP scores results divided between the experimental group (48) and the control group (49). The total sample includes (52) female students and (45) male students. The results indicated that while (31%) of the students in the experimental group showed improvement in their MAP scores, (69%) of these total participants met the growth target by Spring 2022. This percentage of meeting the growth target includes (31%) of females and (38%) of males. On the other hand, although (88%) of the students in the

control group showed improvement in MAP scores in Spring 2022, only (12%) of the total participants, (8%) of females and (4%) of males, in the grade 6 control group met the growth target. None of the students declined or stayed at the same level of scores in both groups. This indicates that when teaching and learning are taking place, MAP scores results are improving for both types of students, however, the percentage of students that met the intended growth target was higher in the experimental group where RCD-PBL curriculum units were implemented in comparison to the control group. This means that the educational approach and the teaching strategies influence the MAP results.

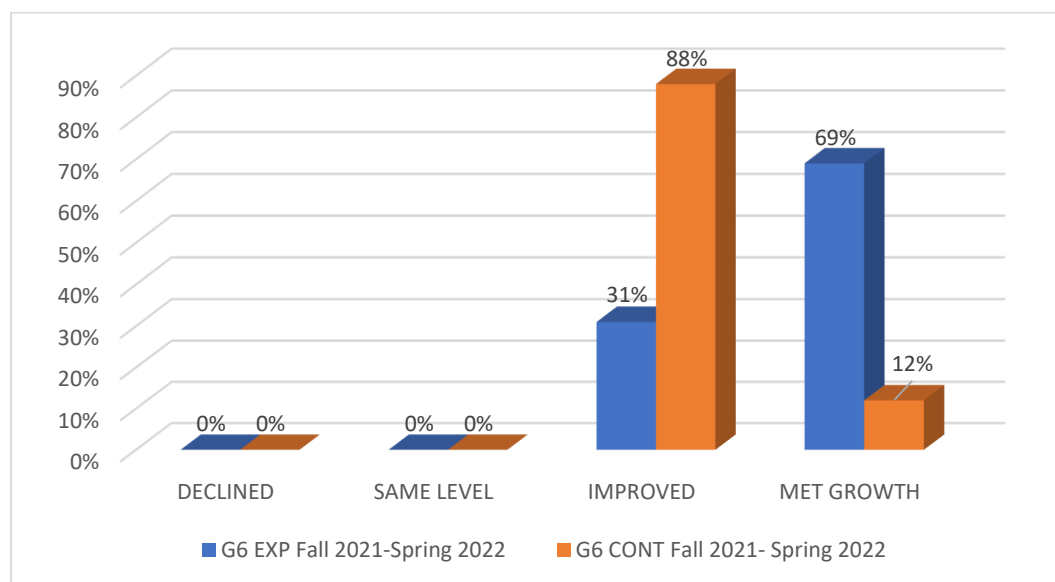


Figure 8: Grade 6 Science MAP Fall 2021-Spring 2022 Overall Achievement Growth

Figure 9 represents the grade 7 students with valid MAP scores results divided between the experimental group (50) and the control group (51). The total sample includes (52) female students and (49) male students. The results indicated that while (52%) of the students in the experimental group showed improvement in their MAP scores, (48%) of these total participants met the growth target by Spring 2022. This percentage of meeting growth target includes (21%) of females and (27%) of males. While (88%) of the students in the control group showed improvement in their MAP scores in Spring 2022, only (6%) of these students of which (2%) are females and (4%) are males, met the growth target. On the other hand, only 3 male students (6%) from the control group stayed at the same level while none of the students in both groups

declined in their MAP scores in Spring 2022 results. This indicates that RCD-PBL implementation affect the MAP scores results in comparison to the textbook-based curriculum.

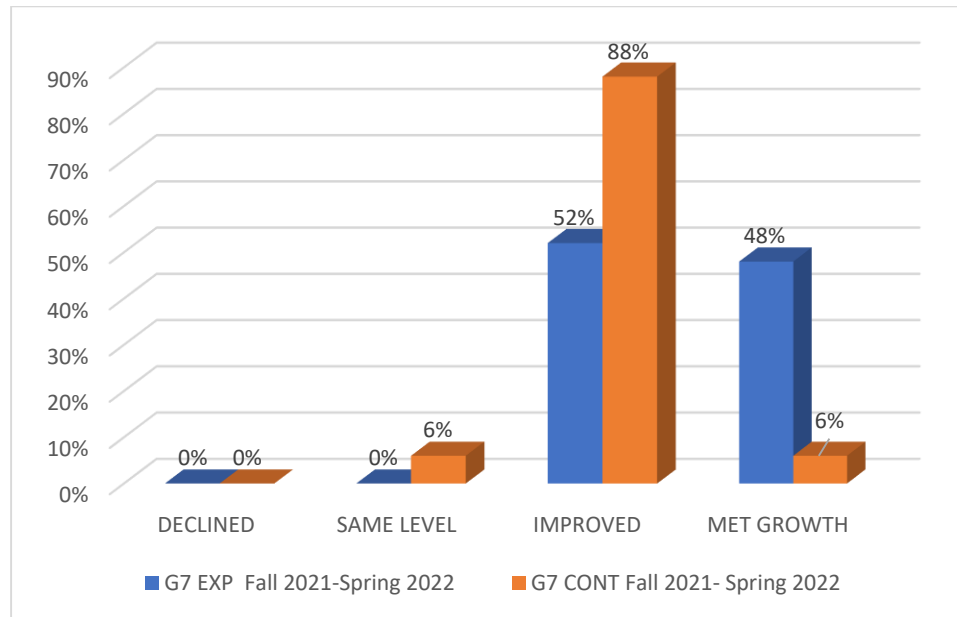


Figure 9: Grade 7 Science MAP Fall 2021-Spring 2022 Overall Achievement Growth

Figure 10 represents the grade 8 students with valid MAP scores results divided between the experimental group (48) and the control group (49). The total sample includes (50) female students and (47) male students. The results indicated that while (44%) of the students in the experimental group showed improvement in their MAP scores, more than half (56%) of these total participants met the growth target by Spring 2022. This percentage of meeting growth target includes (36%) of females and (20%) of males. While (76%) of the students in the control group showed improvement in their MAP scores in Spring 2022, only (10%) of these students of which (6%) are females and (4%) are males, met the growth target. On the other hand, regarding the students who neither improved nor declined, the results indicated that (14%) of the control group participating students stayed at the same level which is represented by six female students (12%) and one male student (2%). This indicates that the RCD-PBL implementation affect the MAP scores results of all grade level students, from grades 6 to 8, in comparison to the textbook curriculum.

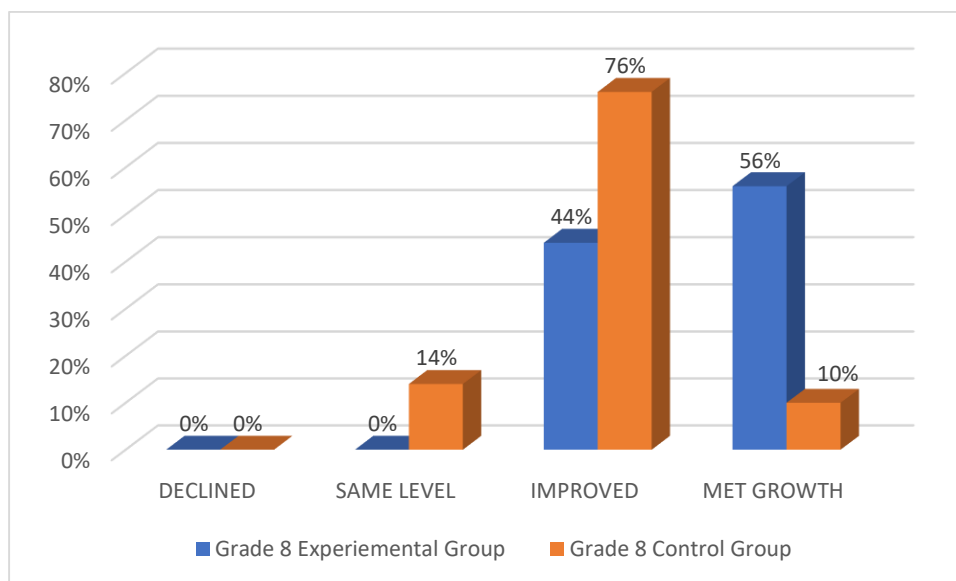


Figure 10: Grade 8 Science MAP Fall 2021-Spring 2022

4.2.3.2 MAP Growth Independent Sample t-test

Independent samples t-test in hypothesis testing is used, to find out if there are any significant differences in the MAP growth scores for the control and experimental groups for middle school science students' MAP scores in Abu Dhabi, UAE. The null and alternative hypotheses for the independent t-test for RQ2 are

- $H_0 : \mu_1 = \mu_2$, there is no statistical significant difference in the MAP growth scores between the control group and the experimental group.
- $H_a : \mu_1 \neq \mu_2$, there is a statistical significant difference in the MAP growth scores between the control group and the experimental group.

where μ_1 and μ_2 are the mean of the control group and the experimental group MAP growth respectively.

Grades 6, 7, and 8 Combined MAP Growth

An independent samples t-test was conducted on MAP growth scores for grades 6, 7, and 8 combined, and from the descriptive statistics results in Table 40, the mean and the standard deviation of the control group ($M=3.17$, $SD=1.684$) and experimental group ($M=5.47$, $SD=1.653$) are significantly different ($p < .001$) with a mean difference of 2.3.

Table 40: Group Statistics for Grades 6, 7, and 8 Combined MAP Growth

Group Statistics					
	Group	N	Mean	Std. Deviation	Std. Error Mean
MAP growth	Control	149	3.17	1.684	0.138
	Experimental	146	5.47	1.653	0.137

Levene's test for equality of variance (Table 41) shows that the p-value = 0.350 > 0.05, therefore, we do not reject the null hypothesis of equal population variances. The MAP growth of the control group is significantly different from the experimental group since $t(293) = -11.827$ and $p < .001$. In conclusion, there is enough evidence that rigorous curriculum design for project-based learning implementation affect grades 6, 7, and 8 middle school science students' MAP scores in Abu Dhabi, UAE, at the 5 % level of statistical significance.

Table 41: Independent T-Test for Grades 6, 7, and 8 Combined MAP Growth

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
MAP growth	Equal variances assumed	0.876	0.350	-11.827	293	0.001	-2.298	0.194	-2.681	-1.916
	Equal variances not assumed			-11.829	292.998	0.001	-2.298	0.194	-2.680	-1.916

Cohen's d statistic is $d = 1.378$. The mean of grades 6, 7 and 8 combined MAP growth for an average student in the experimental group is 1.378 standard deviations higher than the average student in the control group, and hence exceeds the MAP growth of 79% of the control group of students that did not receive the RCD-PBL in grades 6, 7 and 8 students, in Abu Dhabi, UAE. It can be concluded, based on these results, that RCD for PBL had a significantly large effect on the MAP growth in science for grades 6, 7, and 8 students, in Abu Dhabi, UAE, for Fall 2021 to Spring 2022.

Grade 6 MAP Growth

An independent samples t-test was conducted on MAP growth scores for grade 6, and from the descriptive statistics results in Table 42, the mean and standard deviation of the control group (M= 3.98, SD=1.797) and experimental group (M= 6.29, SD= 1.688) are significantly different ($p < .001$) with a mean difference of 2.31. An independent t-test requires the homogeneity assumption to be satisfied. For the control and experimental groups, the population variances of the dependent variable (MAP growth) must be equal. The null hypothesis for Levene's test is that the control and experimental groups we are comparing have equal population variances.

Table 42: Group Statistics for Grade 6 MAP Growth

	Group	N	Mean	Std. Deviation	Std. Error Mean
MAP growth	Control	49	3.98	1.797	.257
	Experimental	48	6.29	1.688	.244

Levene's test for equality of variance (Table 43) shows that the p -value = $0.858 > 0.05$, therefore, we do not reject the null hypothesis of equal population variances. The MAP growth scores of the control group are significantly different from the experimental group, since $t(95) = -6.529$ and $p < .001$. These results suggest that rigorous curriculum design for project-based learning implementation affect grade 6 middle school science students' MAP scores in Abu Dhabi, UAE, compared to the non-PBL instructions at the 5 % level of statistical significance.

Table 43: Independent T-Test for Grade 6 MAP Growth

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
MAP growth	Equal variances assumed	.032	.858	-6.529	95	.000	-2.312	.354	-3.015	-1.609
	Equal variances not assumed			-6.533	94.836	.000	-2.312	.354	-3.015	-1.609

Cohen's d statistic is $d = 1.325$. The relative size of the difference between the mean MAP growth of the experimental and control groups is large and therefore statistically significant. An effect size of 1.325 means that the mean MAP growth of the average student in the experimental group is 1.325 standard deviations higher than the average student in the control group, and hence exceeds the MAP growth of 79% of the control group of students that did not receive the RCD-PBL in grade 6, in Abu Dhabi, UAE.

Grade 7 MAP Growth

An independent samples t-test was conducted on MAP growth scores for Grade 7, and from the descriptive statistics results in Table 44, the mean and standard deviation of the control group ($M=2.73$, $SD= 1.168$) and experimental group ($M= 4.62$, $SD= 1.308$) are significantly different ($p < .001$) with a mean difference of 1.89. An independent t-test requires the homogeneity assumption to be satisfied.

Table 44: Group Statistics for Grade 7 MAP growth

	Group	N	Mean	Std. Deviation	Std. Error Mean
MAP Growth	Control	51	2.73	1.168	.163
	Experimental	50	4.62	1.308	.185

Levene's test for equality of variance (Table 45) shows that the $p\text{-value} = 0.138 > 0.05$, therefore, we do not reject the null hypothesis of equal population variances. The MAP growth scores in science of the control group are significantly different from the experimental group, since $t(99) = -7.684$ and $p < .001$. In conclusion, there is enough evidence that rigorous curriculum design for project-based learning implementation affect grade 7 middle school science students' MAP scores in Abu Dhabi, UAE, at the 5 % level of statistical significance.

Table 45: Independent T-Test for Grade 7 MAP Growth

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
MAP Growth	Equal variances assumed	2.231	.138	-7.684	99	.000	-1.895	.247	-2.384	-1.405
	Equal variances not assumed			-7.675	97.287	.000	-1.895	.247	-2.384	-1.405

Cohen's d statistic is $d = 1.524$. The mean MAP growth of the average student in the experimental group is 1.524 standard deviations higher than the average student in the control group, and hence exceeds the MAP growth of 92 % of the control group of students that did not receive the RCD-PBL in grade 7, in Abu Dhabi, UAE.

Grade 8 MAP Growth

An independent samples t-test was conducted on MAP growth scores for grade 8, and from the descriptive statistics results in Table 46, the mean, and the standard deviation of the control group ($M = 2.84$, $SD = 1.760$) and experimental group ($M = 5.54$, $SD = 1.529$) are significantly different ($p < .001$) with a mean difference of 2.7.

Table 46: Group Statistics for Grade 8 MAP Growth

	Group	N	Mean	Std. Deviation	Std. Error Mean
MAP Growth	Control	49	2.84	1.760	.251
	Experimental	48	5.54	1.529	.221

Levene's test for equality of variance (Table 47) shows that the $p\text{-value} = 0.982 > 0.05$, therefore, we do not reject the null hypothesis of equal population variances. The MAP growth of the control group is significantly different from the experimental group since $t(95) = -8.073$ and $p < .001$. In conclusion, there is enough evidence that rigorous curriculum design for project-based learning implementation affect grade 8 middle school science students' MAP scores in Abu Dhabi, UAE, at the 5 % level of statistical significance.

Table 47: Independent T-Test for Grade 8 MAP Growth

		Levene's Test for Equality of Variances t-test for Equality of Means								
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
MAP Growth	Equal variances assumed	.000	.982	-8.073	95	.000	-2.705	.335	-3.370	-2.040
	Equal variances not assumed			-8.085	93.674	.000	-2.705	.335	-3.369	-2.041

Cohen's d statistic is $d = 1.638$. The mean MAP growth of the average student in the experimental group is 1.638 standard deviations higher than the average student in the control group, and hence exceeds the MAP growth of 92 % of the control group of students that did not receive the RCD-PBL in grade 8, in Abu Dhabi, UAE.

4.2.3.3 MAP Growth One-Way ANOVA

To verify the analysis, a one-way ANOVA was conducted on students' MAP growth scores by RCD-PBL implementation and grade level. The F value in one-way ANOVA helps to identify if the variance between the means of two populations is significantly different. One requirement of the ANOVA test is for the homogeneity of variances to be satisfied which means that the variance of each comparison group is equal. Therefore, the Levene test has been conducted. When $p > .05$ this means there are no significant results, which means the requirement of the homogeneity of variance is met and the ANOVA test adopted is robust.

Grades 6, 7, and 8 MAP Growth

Descriptive statistics in Table 48 show the mean MAP growth of the control ($M=3.17$, $SD=1.684$) and experimental ($M=5.47$, $SD=1.653$) groups.

Table 48: Statistics for Grades 6, 7, and 8 Combined MAP Growth

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		

Control	149	3.17	1.684	0.138	2.90	3.45	0	8
Experimental	146	5.47	1.653	0.137	5.20	5.74	2	9
Total	295	4.31	2.025	0.118	4.08	4.54	0	9

Levene's test in Table 49 shows that the assumption of homogeneity of variances is satisfied ($p > .05$) for grades 6, 7, and 8 combined.

Table 49: Homogeneity Test of Variances for Grades 6, 7, and 8 Combined MAP Growth

Levene Statistic	df1	df2	Sig.
0.876	1	293	0.350

A one-way ANOVA was conducted to compare the effect of RCD-PBL to non-PBL implementation on grades 6, 7, and 8 combined, MAP science growth scores. The results in Table 50 show that there are statistical significant ($p < .001$) differences between the mean MAP growth of the control group and the experimental group at the 5 % level of significance for the three conditions $F(1, 293) = 139.866$, $p < .001$ in grade 6, 7 and 8 combined.

Table 50: ANOVA for Grades 6, 7, and 8 Combined MAP Growth

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	389.455	1	389.455	139.866	0.001
Within Groups	815.853	293	2.784		
Total	1205.308	294			

Grade 6 MAP Growth

Descriptive statistics in Table 51 show the mean MAP growth of the control ($M=3.98$, $SD=1.797$) and experimental ($M=6.29$, $SD=1.688$) groups.

Table 51: Statistics for Grade 6 MAP Growth

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Control	49	3.98	1.797	.257	3.46	4.50	1	8
Experimental	48	6.29	1.688	.244	5.80	6.78	2	9
Total	97	5.12	2.088	.212	4.70	5.54	1	9

Levene's test in Table 52 shows that the assumption of homogeneity of variances is satisfied ($p > .05$) for grade 6

Table 52: Homogeneity Test of Variances for Grade 6 MAP Growth

Levene Statistic	df1	df2	Sig.
.032	1	95	.858

A one-way ANOVA was conducted to compare the effect of RCD-PBL to non-PBL implementation on grade six MAP science growth scores. The results in Table 53 show that there are statistical significant ($p < .001$) differences between the mean MAP growth of the control group and the experimental group at the 5 % of significance for the three conditions $F(1,95) = 42.624$, $p < .001$ in grade 6.

Table 53: ANOVA for Grade 6 MAP Growth

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	129.619	1	129.619	42.624	.000
Within Groups	288.896	95	3.041		
Total	418.515	96			

Grade 7 MAP Growth

Descriptive statistics in Table 54 show the mean MAP growth of the control ($M = 2.73$, $SD = 1.168$) and experimental ($M = 4.62$, $SD = 1.308$) groups.

Table 54: Statistics for Grade 7 MAP Growth

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Control	51	2.73	1.168	.163	2.40	3.05	0	6
Experimental	50	4.62	1.308	.185	4.25	4.99	2	7
Total	101	3.66	1.557	.155	3.36	3.97	0	7

Levene's test in Table 55 shows that the assumption of homogeneity of variances is satisfied ($p > .05$).

Table 55: Homogeneity Test of Variances for Grade 7 MAP Growth

Levene Statistic	df1	df2	Sig.
2.231	1	99	.138

A one-way ANOVA was conducted to compare the effect of RCD-PBL to non-PBL implementation on grade seven MAP science growth scores. The results in Table 56 show that

there are statistical significant ($p < .001$) differences between the mean MAP growth of the control group and the experimental group at the 5 % of significance for the three conditions $F(1,99) = 59.045$, $p < .001$ in grade 7.

Table 56: ANOVA for Grade 7 MAP Growth

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	90.618	1	90.618	59.045	.000
Total	242.554	100			

Grade 8 MAP Growth

Descriptive statistics in Table 57 show the mean MAP growth of the control ($M = 2.84$, $SD = 1.760$) and experimental ($M = 5.54$, $SD = 1.529$) groups.

Table 57: Statistics for Grade 8 MAP Growth

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Control	49	2.84	1.760	.251	2.33	3.34	0	8
Experimental	48	5.54	1.529	.221	5.10	5.99	3	8
Total	97	4.18	2.131	.216	3.75	4.60	0	8

Levene's test in Table 58 shows that the assumption of homogeneity of variances is satisfied ($p > .05$).

Table 58: Homogeneity Test of Variances for Grade 8 MAP Growth

Levene Statistic	df1	df2	Sig.
.000	1	95	.982

A one-way ANOVA was conducted to compare the effect of RCD-PBL to non-PBL implementation on grade seven MAP science growth scores. The results in Table 59 show that there are statistically significant ($p < .001$) differences between the mean MAP growth of the control group and the experimental group at the 5 % of significance for the three conditions $F(1,95) = 65.171$, $p < .001$ in grade 8.

Table 59: ANOVA for Grade 8 MAP Growth

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	177.410	1	177.410	65.171	.000
Within Groups	258.611	95	2.722		
Total	436.021	96			

MAP Fall 2021- Spring 2022 Scores

Figure 11 shows growth in MAP mean scores for middle school science students (grades 6, 7, and 8) MAP Fall and Spring scores in Abu Dhabi, UAE. The MAP Spring mean scores of all grade levels are higher than their mean MAP Fall scores. The MAP scores for Spring show higher scores for the experimental groups compared to the control groups for grade 6, grade 7, and grade 8. These results suggest that when middle school students are taught using RCD-PBL higher MAP means scores are attained in comparison to when they are taught using the traditional approach, textbook-based curriculum.

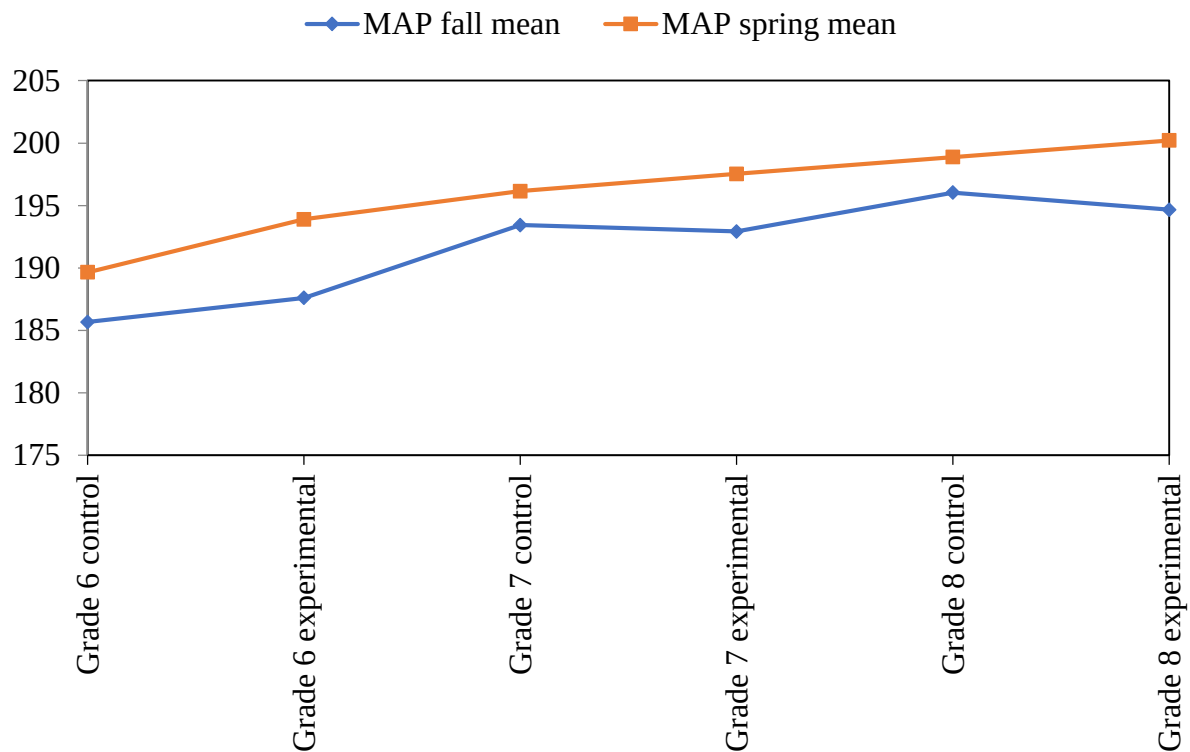


Figure 11: Mean MAP Fall and Spring Scores for Grades 6, 7, and 8.

4.2.3.4 Summary of RQ2 Quantitative Results

For RQ2, with regards to investigating the effect of RCD-PBL implementation on middle school science MAP scores results, descriptive analysis of the MAP projected growth achievement was conducted along with descriptive and inferential statistics, independent sample t-test and one-way ANOVA on MAP growth scores to investigate if there is any statistically significant difference between RCD-PBL (PBL) versus textbook-based curriculum (non-PBL). The Descriptive analysis of the MAP projected growth achievement showed that:

- 58% of the participating students in all middle school grade levels (grades 6,7, and 8) experimental group have met the target of the Projection Growth that each student must achieve within this academic year in comparison to 11% of the control group participating students.
- 63% of the participating students in all middle school grade levels (grades 6,7, and 8) achieved better results in their science MAP exam in Spring 2022. On the other hand, (14%) of all the participating students from the control group stayed at the same level while the experimental group students either improved or met growth. This indicates that the RCD-PBL implementation affects the MAP scores results of all grade level students, from grade 6 to 8, in comparison to the traditional educational approach.
- Both genders showed improvement in their MAP scores, however, more Male students have met the MAP projected growth in grade 6 (42%) and grade 7 (31%) while more female students have met the MAP projected growth in grade 8 (42%).

The independent samples t-test results show that there is statistical evidence that rigorous curriculum design for project-based learning implementation affects middle school science students (grades 6, 7, and 8) MAP growth scores for MAP fall-spring (2021 to 2022) in Abu Dhabi, UAE, at the 5 % level of significance. In addition, one way ANOVA results agree with the results from the independent t-tests in that there are statistically significant differences between the RCD-PBL groups versus textbook-based curriculum groups for grades 6, 7, and 8 in mean MAP growth scores in science for MAP Fall-Spring (2021 to 2022) in Abu Dhabi, UAE, at the 5 % level of significance. Furthermore, descriptive statistics showed that the MAP Spring mean scores of grades 6, 7, and 8, are higher than the mean MAP Fall scores, for both the control and experimental groups. The MAP scores for spring show higher scores for the experimental group compared to the control group for grade 6, grade 7, and Grade 8. This shows

that the RCD-PBL rigorous curriculum design for project-based learning implementation has an impact on middle school science students' MAP scores in Abu Dhabi, UAE, since all MAP spring 2022 experimental group mean scores for grades 6, 7, and 8 are higher than their corresponding control group MAP spring 2022 scores.

4.2.4 Teachers' Perceptions-Questionnaire

This section presents the results of the third research question "What are teachers' perceptions towards rigorous curriculum design for project-based learning development and implementation in science". To that end, an online questionnaire developed on Survey Monkey was sent to all middle school science teachers via email to investigate their perceptions regarding factors associated with the effectiveness of the development and proper implementation of a curriculum. A total of twenty-five complete responses were received and analysed using the Statistical Package for Social Sciences. A 44-question survey with 63 items was conducted and divided into four parts to reflect the factors that influence teachers' perceptions based on the conceptual framework of the study: demographics that embed teacher qualifications and experience, professional development, RCD for PBL receptivity and understanding (alignment and assessment). All results and data were computed, compiled, and analysed (descriptively and statistically) on this platform. Furthermore, the instrument demonstrated strong reliability for N=25 as indicated by Cronbach's alpha of 0.910 (Table 60).

Table 60: Reliability Test Result of Teachers' Questionnaire

Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.917	.910	63

4.2.4.1 Descriptive Statistics

The total number of participating teachers in the questionnaire was 25 science teachers all of whom were involved in the development and implementation of RCD-PBL curriculum units. A general overview of the sample demographic information broken down by gender, mother tongue, campus, teaching and curriculum experience (years), grade level taught, and academic qualification are reported and analyzed in the below tables and charts. This section is

followed by three other sections related to teachers' professional development, receptivity, and finally their understanding in terms of alignment and assessment.

Section 1: Demographics

Table 61: Demographic Information (Teachers' Gender) of the Participating Teachers

Gender	Frequency	Percentage
Male	7	28.00%
Female	18	72.00%

Table 62: Participating Teachers' Mother Tongue

Mother Tongue	Frequency	Percentage
English	16	64.00%
Arabic	7	28.00%
Others	2	8.00%

Table 63: Campus in which Participating Teachers (N=25) Currently Work

Campus	Frequency	Percentage
Boys Campus	12	48.00%
Girls Campus	13	52.00%

The participants include seven males which represent (28%) and eighteen females which represent (72%) of the whole percentage. In addition, 16 out of the 25 participating teachers (64%) are native English speakers, seven teachers are of Arab descent which represents (28%) and only 2 Filipino teachers representing (8%) of the whole sample percentage have Tagalog as their mother tongue. These participants are approximately evenly spread out with respectively (48%) and (52%) working at the boys' school and girls' school campuses.

Teachers Experience

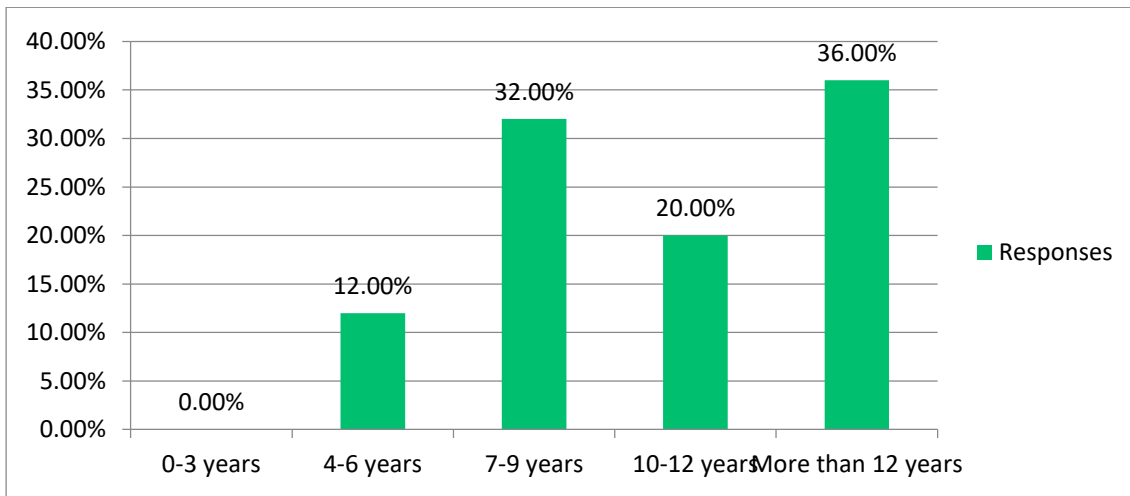


Figure 12: Participating Teachers' Total Years of Experience

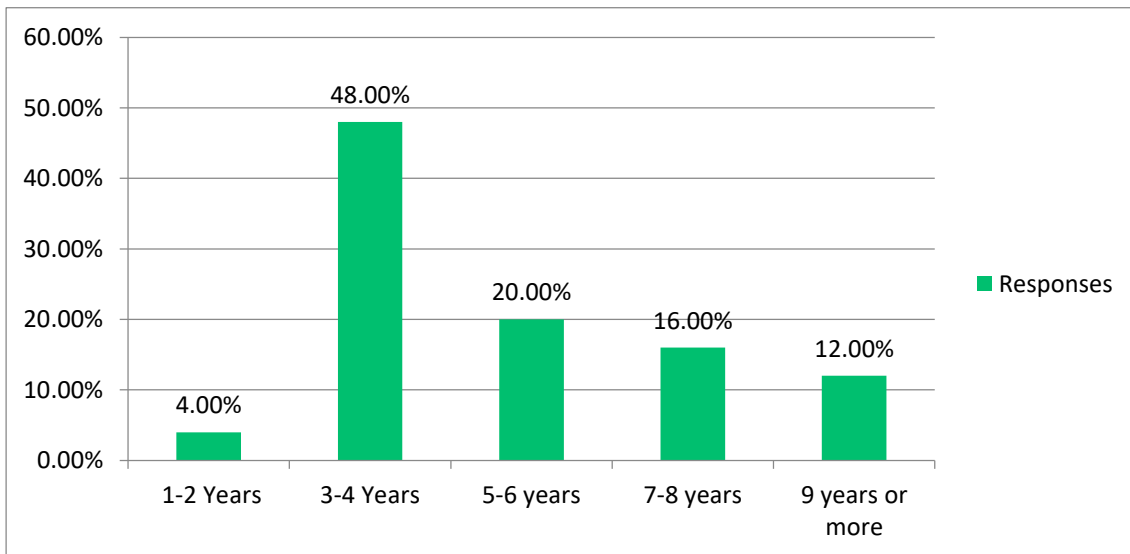


Figure 13: Participating Teachers' Total Years of Experience in the School

Moreover, while more than half of the participants have more than ten years of teaching experience (56%, n=25), 12% have been working for more than ten years at the school. The other half of the participants are divided into two sections, the first one represents (32%) with an average experience in teaching of (7-9) years while the second section represents (12%) with (4-6) years of experience (Figure 12). Additionally, most of the teachers (48%) have been working for (3-4) years at the school where the study is taking place, followed by (20%) and

(16%) respectively representing (5-6) and (7-8) years of experience. Finally, only 4% of the teaching staff are either new or have been in the school for two years (Figure 13).

Furthermore, while most of the teachers are teaching at least two grade levels the majority teach middle years grades 6, 7, and 8 with respectively (40%), (48%), and (40%). Out of the 25 teachers, 8 teachers representing (32%) of the total sample teachers teaches grade 9, and 9 teachers which represent (36%) teach grade 10 (Table 64).

Table 64: Grade Levels Taught by Participating Teachers

Grade levels taught	Frequency	Percentage
Grade 6	10	40.00%
Grade 7	12	48.00%
Grade 8	10	40.00%
Grade 9	8	32.00%
Grade 10	9	36.00%

Table 65 presents the highest level of education degree attained by each participant. Looking at the findings, most of the teachers either hold a bachelor's degree (44%, n=25) or a master's degree (40%, n=25) followed by 12% holding a higher Diploma or a doctorate (4%, n=25).

Table 65: Participating Teachers' Highest Academic Qualifications

Qualification	Frequency	Percentage
Bachelor's degree	11	44.00%
Higher Diploma	3	12.00%
Master's degree	10	40.00%
Doctorate	1	4.00%

In addition, cross-tabulation of the grade level taught against the teacher's qualifications (Figure 14) shows that most of the middle school science teachers (n=17) that teach grades 6, 7, and 8 either hold a bachelor or a master's degree with respectively (32%, n=25) and (36%, n=25). One grade 8 teacher holds a higher diploma while grades 9 and 10 teachers' qualifications are spread out evenly across bachelor, higher diploma, and master's degree holders with respectively (8%, n=25) each. Finally, one grade 10 teacher who represents (4%, n=25) of the whole sample holds a doctorate.

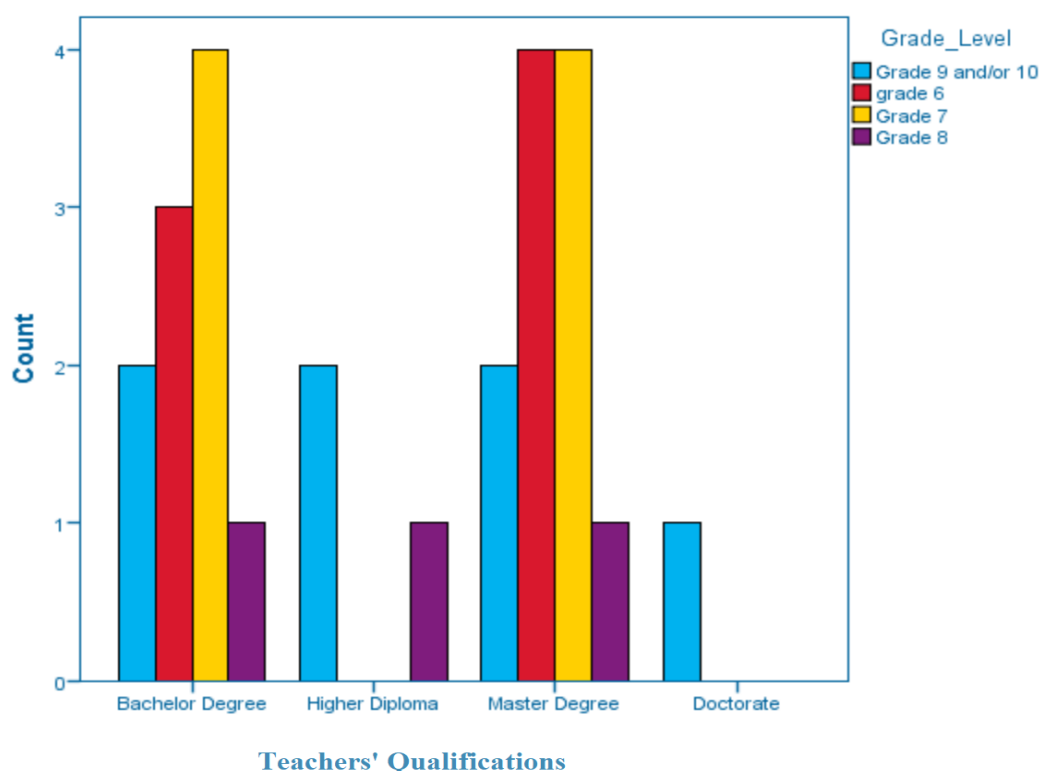


Figure 14: Grade Level Taught and Teachers' Qualifications Cross-tabulation Count

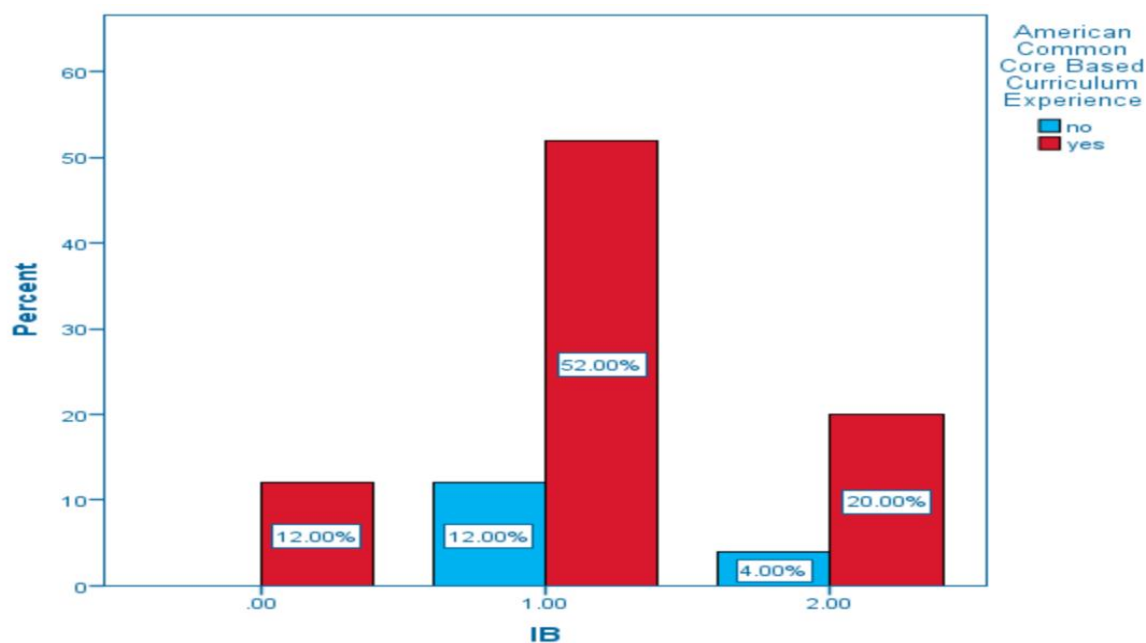
Curriculum and Framework Experience

Table 66: Teachers' Respondent to Curriculum Experience

Demographics- Experience		Frequency	Percentage
American Common Core Based Curriculum	Yes	21	84%
	No	4	16%
International Baccalaureate	None of the above	14	56%
	Primary Year Program (PYP)	2	8%
	Middle Year Program (MYP)	8	32%
	Diploma Program (DP)	1	4%

Looking through the curriculum and framework experience represented in Table 66, it has been shown that while (84%, n=21) of the middle school science participating teachers have prior experience in teaching American Common Core Based Curriculum (AC), more than half

of the teachers (56%, n=14) have no prior experience or exposure to the International Baccalaureate program (IB). However, 32% of the participating teachers were familiar with and had experience in Middle Years Program (MYP) programs followed by 8% with Primary Years Program (PYP) and finally 4% with the Diploma Program (DP). Since the study has been conducted in an American and International Baccalaureate curriculum school, the cross-tabulation between teachers' prior experience with the AC and the IB pinpoint more about the teachers that have been exposed to several frameworks and curricula. It has been shown that while more than half (52%) of the teachers that have prior experience with the AC have delivered one of the IB programs (PYP, MYP, or DP), (20%) have delivered two programs, and



(12%) have no prior experience in the IB program (Figure 15).

Figure 15: Crosstabulation Between American Curriculum and International Baccalaureate

Section 2: Professional Development

Analyzing the second part of the teachers' questionnaire related to the efficiency of the professional development training workshops, it has shown that most of the teachers (92%, n=23) strongly agreed with the fact that the RCD has equipped them with the necessary knowledge and skills needed to develop/redesign a curriculum using the RCD model, 4 % of

the teachers (n=1) either agree or neither agree nor disagree to this statement (Figure 16). Similarly, 92 % of the teachers (n=23) strongly agreed on the fact that the NGSS training workshops have equipped them with the necessary knowledge and skills needed to unpack the NGSS standards while 8 % of the teachers (n=2) agreed on this statement. Finally, while 80% of the teachers strongly agreed on the fact that PBL training workshops have supported them to implement such key approaches and assessments in their classroom, and 20 % of the participating teachers (n=5) agreed with this statement.

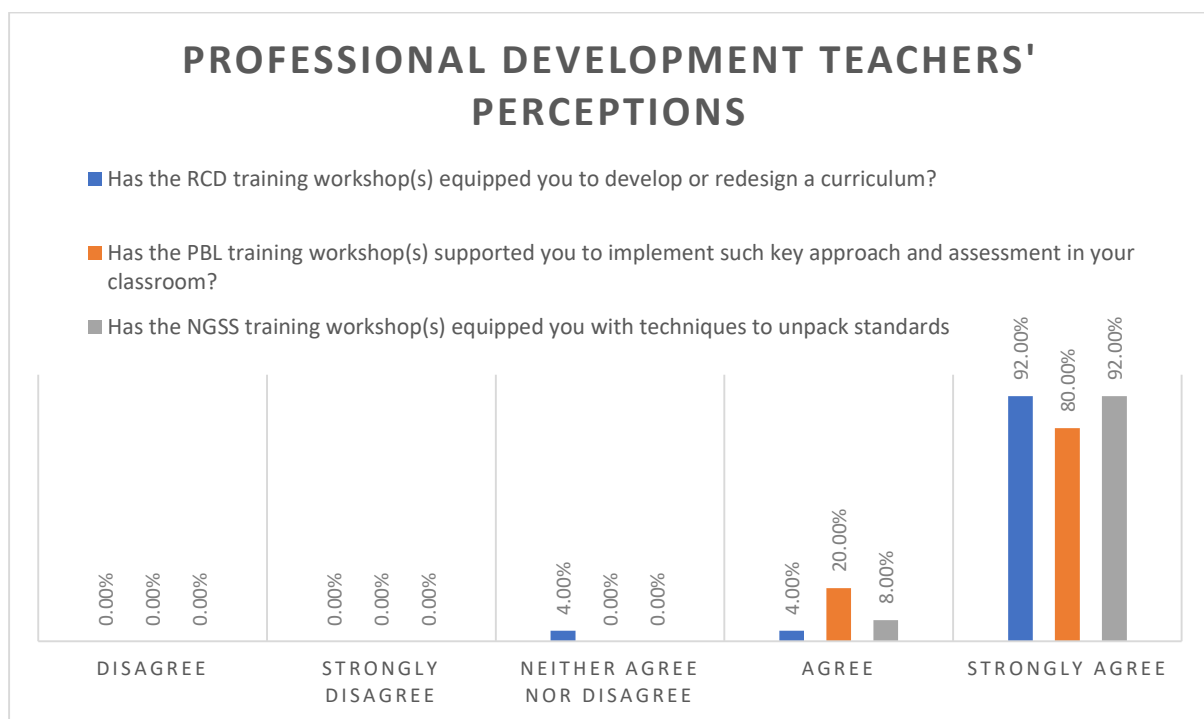


Figure 16: Professional Development Teachers' Perceptions (N=25)

Section 3: RCD-PBL Teachers' Receptivity Results

This section is divided into three parts, two of which evaluates teachers' receptivity towards the Rigorous Curriculum Design roadmap adopted in writing, designing, and implementing project-based learning unit of study. Teachers were asked to think about the statements given in each section and state their decision based on the Likert scale by using a number from one to five (1 = "Strongly Disagree", 2 = "Disagree", 3 = "Neither Agree nor Disagree", 4 = "Agree", and 5 = "Strongly Agree"). The third part highlighted a list of key components of the RCD process whereby each participant was asked to select all their areas of

strengths in delivering RCD instructional units to students to reflect on professional development efficiency.

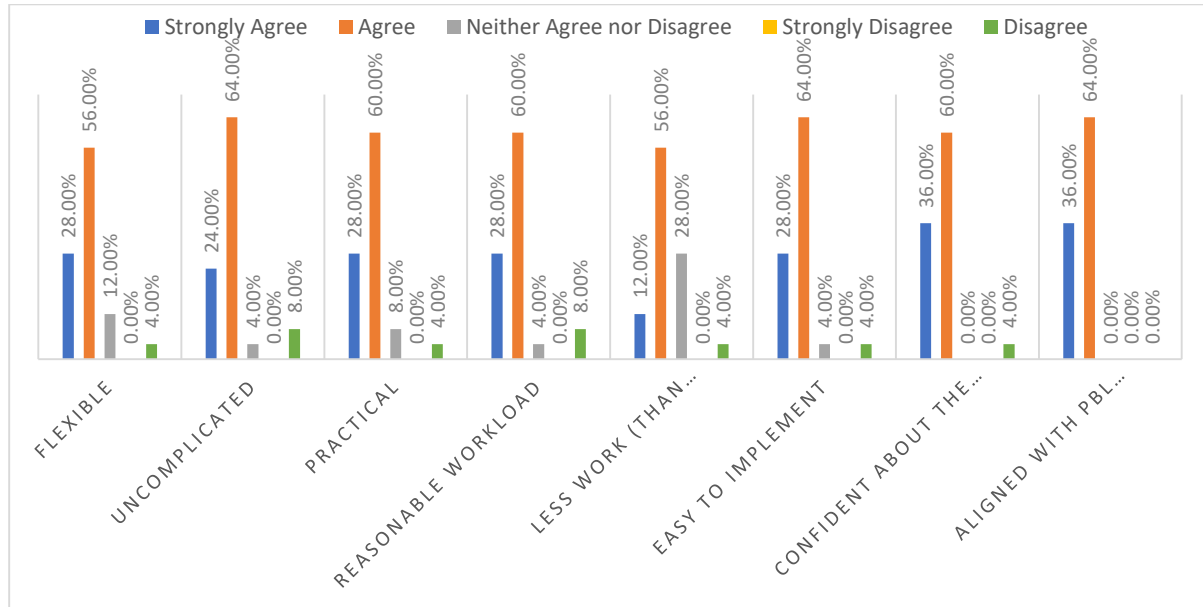


Figure 17: Teachers' Receptivity Towards RCD- PBL

Figure 17 illustrates the analysis of the collected results from 25 middle school science participating teachers towards RCD-PBL receptivity. The results indicate that over (84%) of teachers' responses are categorized between strongly agree and agree in most of the related items. The highest percentage was allocated to the alignment of RCD with the PBL components (100%), its ease of implementation (92%) as well as its uncomplicated steps and process to designing such curriculum units with (88%) of teachers' agreement on each statement. In addition, more than half of the participating teachers strongly agree with the practicality (60%) and the flexibility (56%) of the RCD-PBL implementation.

On the other hand, the responses with the least percentage were linked to the workload. While (88%) of teachers' response are categorized between strongly agree and agree and believes that RCD-PBL requires less work than previous unit planner preparation, (4 %) neither agree nor disagree with this statement. Finally, while a minority of participants less or equal to (8%, n=2) have disagreed on all statements except the alignment with PBL, not a single teacher strongly disagreed with any statement.

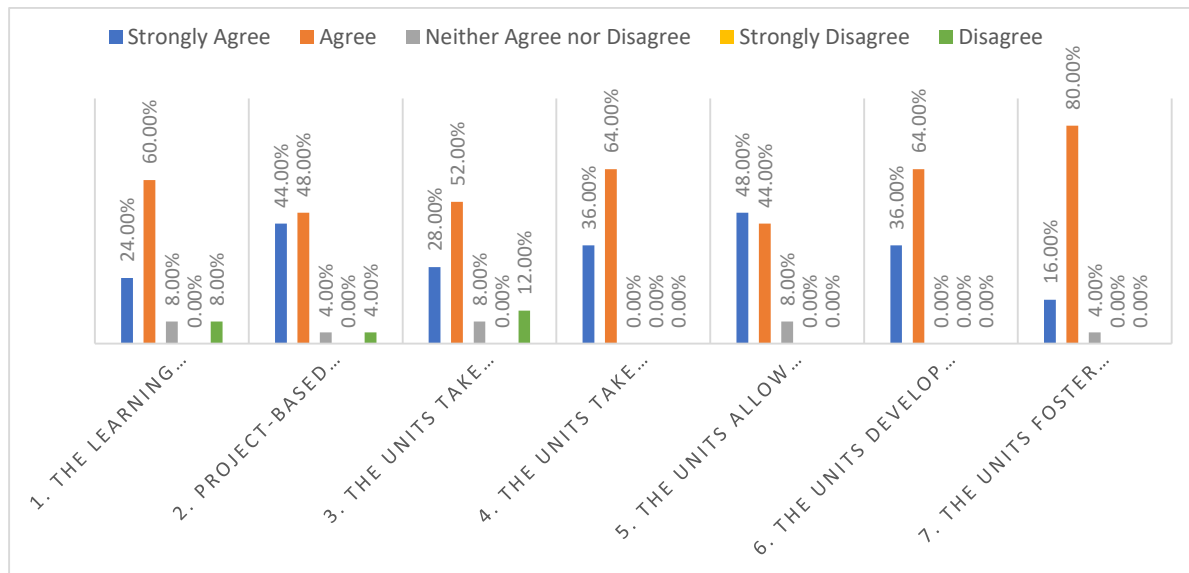


Figure 18: Teachers' Perception Towards Project-Based Learning Units Development Using the RCD Model

Figure 18 shows the results of teachers' perception towards project-based learning units' development using the RCD model. The results indicate that over (80%) of teachers' responses are categorized between strongly agree and agree in all the related statements. The highest percentage of agreement (80%, n=20) was allocated to the following statement "the units foster students' own disposition to recognize when and how to use the key competencies and be willing to do so" followed by (64%, n=16) for each statement: "the units take into consideration Emirati students society and culture" and "the units develop students' competency in Thinking" and (60%, n=15) affirm that the learning experiences and assessment in RCD-PBL encourage collaboration with other members. In addition, (48%, n=12) of the participating teachers strongly agreed on the fact that the RCD-PBL units allow students to use the knowledge acquired in meaningful real-world contexts followed by (44 %, n=11) that strongly believed that PBL assessment encourages students to contribute to society. While no teachers strongly disagreed with any statement, (12%, n=3) disagreed with the third statement "the units take into consideration individual differences among students".

Table 67: Frequency Analysis of Teachers’ Selection to the RCD Process Key Components Strength Areas

RCD Key Components	Frequency	Percentages
Planning Engaging and Relevant Learning Activities	19	76.00%
Writing Standards-Based Student Summative Assessments	15	60.00%
Writing Standards-Based Student Formative Assessments	14	56.00%
Write and Develop project-based assessment that meets the standards	17	68.00%
Differentiating Student Instruction in the Classroom	10	40.00%
Student Behavior Management	11	44.00%
Matching Student Learning Styles to Teaching Strategies	12	48.00%
Instructional Pacing and Time Management in the Classroom	12	48.00%
Diagnostic/Prescriptive Teaching	12	48.00%
Use of Data to Inform Instructional Lessons	13	52.00%
Use of Technology to Effectively Manage and Deliver Teaching/Learning	13	52.00%
Collaboration with Colleagues	20	80.00%
Providing Students with Effective Feedback on Learning	11	44.00%

Table 67 denotes the RCD process key components' strength areas selected by teachers. Looking at the results, most of the teachers (80%) have highlighted “collaborative with colleagues” as their key component strength in designing and delivering RCD-PBL instructional units to students. This indicated that all RCD-PBL curriculum units were written collaboratively by all science members. In addition, the efficiency of the professional development sessions has been recognized as more than (60%) of the participating teachers have selected “Planning Engaging and Relevant Learning Activities”, “Write and Develop project-based assessment that meets the standards” and “Writing Standards-Based Student Summative Assessments” as their strength areas.

Section 4: Teachers’ perception results towards RCD-PBL understanding: alignment and assessment

This section is divided into three parts that encompass Likert scale type of questions ranging from strongly agree=5, Agree=4, neither agree nor disagree=3 Disagree=2, strongly disagree=1 and evaluates teachers’ perceptions towards the RCD-PBL curriculum units’ implementation alignment and assessment. Looking at Figure 19, it has been shown that all teachers’ responses (100%) are categorized between strongly agree and agree when it comes to the relationships and alignment that exist between the academic content standards to be taught (NGSS), statements of inquiry set, global context to frame classroom inquiry, and direct purposeful learning experiences provided to the student through the unit activities as well as the

alignment between “the learning experiences provided to the student through the unit activities and the project-based learning assessment used in the unit”. In addition, (95.84%, n=23) of the participating teachers showed their agreement on the alignment that exists between the learning resources provided in the curriculum, and the learning activities of the unit/lesson as well as the direct relationship that exists between academic content standards to be taught (NGSS), and the PBL assessments provided to the student.

Moreover, while (92%) of the teachers expressed their agreement with how the implementation of the current curriculum reflected the intended written curriculum, a minority of participants (8%) either disagreed or neither agreed nor disagree with this statement. Furthermore, although no participant selected strongly disagree with any of the statements provided, (88%) of the teachers’ agreements were observed regarding the appropriateness amount of time spent in planning the delivery of instruction next to understanding how to use information gained from the assessment in planning the next unit/lesson to be taught. However, (12%) of the participating teachers either disagree or neither agree nor disagree with these statements.

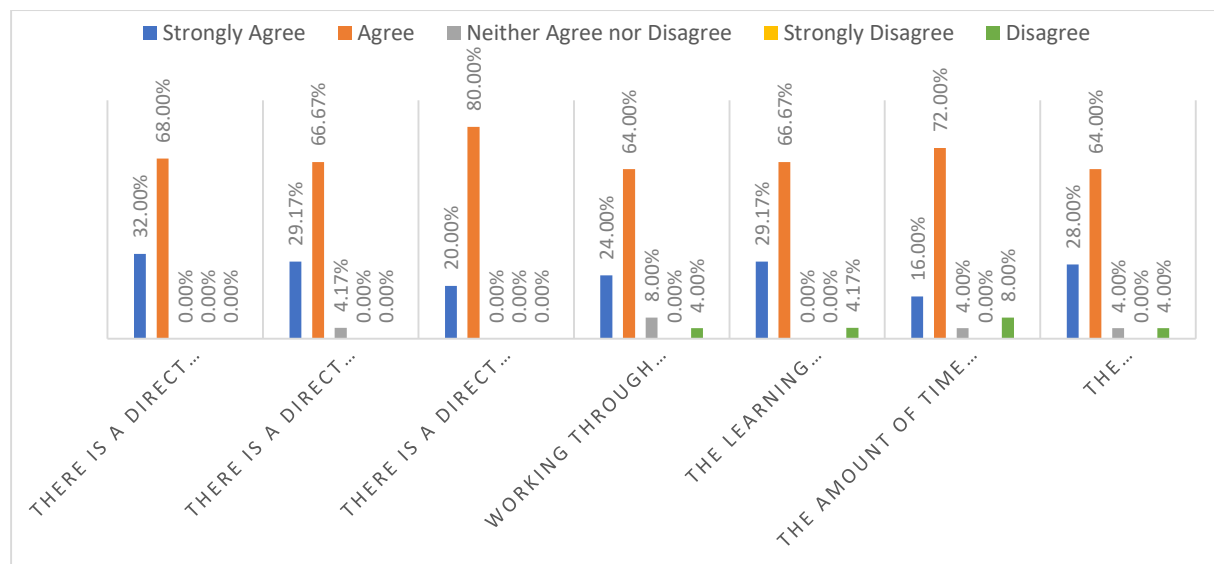


Figure 19: Teachers’ Perceptions towards the RCD-PBL Curriculum Units’ Implementation Alignment

After the implementation of the first RCD-PBL unit, it has been shown in Figure 20 that at least more than 25% of the students demonstrated improved achievement as measured against

their attainment on the pre-post assessments of the unit. The highest percentage was linked to the agreement of (68%, n=17) of the teachers on the fact that 50% to 74% of the students have demonstrated improved achievement. Followed by (20%, n=5) of the teachers that strongly agreed that more than 75% of their students demonstrated improved achievement. Finally, (12%, n=3) of the teachers affirm that only 25% to 49% of their students have demonstrated improved achievement.

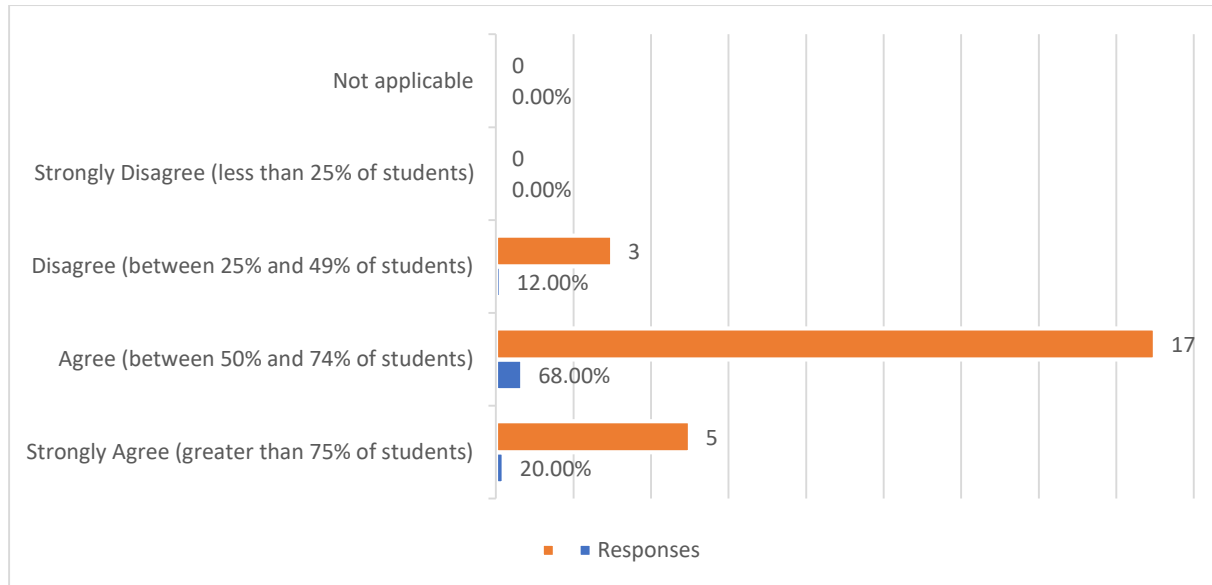


Figure 20: Teachers' Perceptions towards Pre-Post Students' Achievement Results After first RCD-PBL Unit implementation

Table 68 identifies the descriptive statistics which include the mean, standard deviation, and percentages regarding the (7) statements that are related to the RCD-PBL evaluation specifically focusing on assessment attributes. Looking at Table 59, more than (84%) of the participating teachers strongly agreed or agreed with all the statements while none strongly disagreed with any. The mean scores results are presented to identify the highest and lowest rates of RCD-PBL assessment teacher consensus. While a mean closer to 4 or 5 indicates that teachers have a common consensus and agreed on the RCD-PBL assessment statement evaluation, a mean closer to 1 or 2 indicates their disagreement. The range is between (3.80) and (4.44) with a general mean score of (4.12). As reported in Table 68, the vast majority of respondents agreed on six statements (statements 1,3,4,5,6, and 7) while strongly agreed with one statement (statement 2:). The highest mean of teachers' consensus towards RCD-PBL

evaluation is (4.44) with (0.58) standard deviation where (96%) of the middle school teachers were equally divided between (48%) strongly agree and (48%) agree. These teachers stated that the project-based learning assessment (GRASPS) used in the units are authentic and relevant to the context of your Emirati Students. On the other hand, the results of the lowest mean of teachers' consensus towards RCD-PBL evaluation is (3.80) with (1.00) standard deviation where (80%) of the participating teachers were between (16%) strongly agree and (64%) agree. These teachers indicated that the students' voices and choices are reflected in the unit and assessment. The rest of the teachers either they neither agree nor disagree (12%) or disagree (8%) with this statement. Based on these results, it can be highlighted that BIE PBL elements and RCD attributes are properly integrated and identified by teachers through their agreement on RCD being a student-centered process (84%) that reflects students' voice and choice in the assessment tasks (80%). In addition, (96%) of teachers agreed with the following statements: PBL assessment (GRASPS) are authentic and contextual, engage students in meaningful problems or questions, correlated to the standards and skills that need to be assessed, address differentiation, and meet the needs of all students. In addition, (88%) of teachers affirmed by either agreeing (56%) or strongly agreeing (32%) on how RCD-PBL ensured coherence in the middle school science curriculum.

Table 68: Frequency Analysis of Teachers' Perceptions towards RCD-PBL Assessment (% Distribution)

	Disagree		Strongly Disagree		Neither Agree nor Disagree		Agree		Strongly Agree		Descriptive Statistics	
	#	%	#	%	#	%	#	%	#	%	Mean	SD
1.The RCD planning process is student centered.	0	0%	0	0%	4	16%	11	44%	10	40%	4.00	1.25
2. Project-based learning assessment (GRASPS) used in the units are authentic and relevant to the context of your Emirati Students	1	4%	0	0%	0	0%	12	48%	12	48%	4.44	0.58
3.Project-based learning assessment (GRASPS) are correlated to the standards and skills that need to be assessed (NGSS)	0	0%	0	0%	1	4%	15	60%	9	36%	4.20	0.81
4.Project-based learning units and assessment engaged students in problems or questions to make learning more meaningful	1	4%	0	0%	0	0%	18	72%	6	24%	4.20	0.5
5.Students' voice and Choice are reflected in the unit and assessment.	2	8%	0	0%	3	12%	16	64%	4	16%	3.80	1.00
6.Project-based learning units developed using the RCD process addresses differentiation of instruction in the unit/lesson planners	1	4%	0	0%	0	0%	19	76%	5	20%	4.16	0.48
7.The project-based learning units developed using the RCD model ensured coherence in middle school science curriculum that is responsive and relevant to all students needs	0	0%	0	0%	3	12%	14	56%	8	32%	4.00	1.23

4.2.4.2 Summary of RQ3 Quantitative Results

To answer RQ3, quantitative analysis of a questionnaire and qualitative analysis of interview transcripts were performed. In terms of teachers' perceptions of RCD-PBL development and implementation quantitative analysis results from the questionnaires show that:

Professional Development:

Findings related to the teachers' perceptions of the efficiency of the professional development training workshops show that most of the teachers (96%) affirm that the RCD has equipped them with the necessary knowledge and skills needed to develop or redesign a curriculum using the RCD model. Similarly, all respondents affirm that the NGSS training workshops have equipped them with the necessary knowledge and skills needed to unpack the NGSS standards. Finally, all teachers state that PBL training workshops have supported them to implement such key approaches and assessments in their classrooms.

Receptivity

Analysis results show that most teachers view the RCD roadmap adopted in writing and designing the PBL unit of study as flexible, uncomplicated, practical, easy to implement, confident about the implementation, and aligned with PBL components. They also were confident about the implementation and believed that the workload was reasonable, and that it required less work and planning time than before.

Understanding

With regards to teachers' perceptions towards PBL units developed using the RCD model at least 80% of the respondents believed that: the learning experiences and assessments in the units encourage students to work collaboratively with others and to contribute to society; the units take into consideration individual differences among students, and Emirati students society and culture; the units allow students to use the knowledge acquired in meaningful real-world contexts and develop students' competency in thinking; the units foster students' own disposition to recognize when and how to use the key competencies. These findings are in agreement with Haatainen and Aksela (2021) who suggested that the PBL curriculum offers multiple advantages which range from active learning, increase in skills, knowledge, motivation, collaboration, student-centered learning, and education versatility, although teachers'

perceptions vary from one country to another. Marzano (2007) suggested that students' performance levels increase when instructions are based on real-world context; PBL promotes active learning, demonstration, writing, and high-order thinking skills. Vygotsky emphasized the importance of the cultural and social context in teaching and, therefore, suggested that it has a solid connection with PBL (Mustafa, Nordin & Razzaq 2020).

On the key components of the RCD process, the teachers mostly responded that collaboration with colleagues followed by planning, engaging and relevant learning activities were their strengths in delivering RCD-PBL instructional units to students. This is in line with Handler (2010) and Luciano (2014) who highlighted the need for teachers' involvement in building and designing high-quality curriculum while collaboratively and cooperatively working with school leaders leading to an effective alignment between the curriculum's core elements.

In terms of understanding the alignment and assessment of the RCD-PBL framework more than 88% of the teachers state that: there is a direct relationship between the academic content standards to be taught (NGSS), statements of inquiry set, global context to frame classroom inquiry, and direct purposeful learning experiences provided to the student through the unit activities; there is a direct relationship between academic content standards to be taught (NGSS), and the PBL assessments provided to the student; there is a direct relationship between the learning experiences provided to the student through the unit activities and the PBL assessment used in the unit; working through the unit and lesson planning has allowed the teacher to understand the information gained from the assessment and its use in planning the next unit/lesson to be taught; the learning resources provided in the curriculum are aligned to the learning activities of the unit/lesson; the amount of time spent in planning the delivery of instruction is appropriate; the implementation of the current curriculum reflected the intended written curriculum. These results agree with the findings from the literature. Eckersall (2017) studied how implementing RCD units will affect students' achievement in three junior high schools in Southern California. His study followed a mixed-method approach, where it revealed an increase in students' achievement in high-stakes tests by acquiring 21st-century skills when implementing an RCD unit planning organizer that aligns the three core elements of a curriculum. The integration of the three dimensions, Science and Engineering Practices (SEP), Disciplinary core ideas (DCI), and Cross Cutting Concepts (CC) are illustrated in the standards

also known as performance expectation (PE) to make SEP more meaningful to students by engaging them in practices that allow them to investigate the natural world they live in and provide solutions to real-world problems (Schwarz, Reiser & Cynthia Passmore 2017; Holthuis et al. 2018; Three Dimensional Learning 2020). Stanford University research study team found that the incorporation of PBL that is based on rigorous performance tasks and group work will ensure effective implementation of the NGSS-aligned curricula (Holthuis et al. 2018) whereby its three dimensions are not only incorporated in its standards but also its instructional strategies and assessment (NGSS Lead States 2013). Moreover, Condliffe et al. (2017) have highlighted that the impact of the NGSS in developing students' conceptual knowledge and deepening their skills aligns perfectly with PBL objectives and goals.

At least 80% of the respondents to the questionnaire stated that the RCD planning process is: student-centered; PBL assessment (GRASPS) used in the units are authentic and relevant to the context of Emirati Students and are correlated to the standards and skills that need to be assessed (NGSS); PBL units and assessment engaged students in problems or questions to make learning more meaningful; students' voice and choice are reflected in the unit and assessment; PBL units developed using the RCD process addresses differentiation of instruction in the unit/lesson planners; PBL units developed using the RCD model ensured coherence in the middle school science curriculum that is responsive and relevant to all students' needs. The findings are supported by the Buck Institute for Education (2019b), which stated that authentic projects ensure student autonomy, accountability, authenticity, reflection, voice, and choice as they are mostly student-driven and related to real-life topics and problems. It has been shown that a student-centered design curriculum also known as a learner-centered curriculum leads to high student achievement in different cycles and subjects such as Mathematics, English, and Science (Polly et al. 2015; Üzümlü & Pesen 2019).

4.3 Qualitative Data Results Analysis

The second part of the explanatory sequential mixed method design, which covers the qualitative part, is presented in this section. This section includes the interview transcript results of six middle school science teachers who were part of the development and implementation process of the RCD-PBL from grades 6 to 8 and whereby the findings should help in clarifying and strengthening the results of the quantitative data (teachers' questionnaire and the students' SSKT and MAP exam results in science).

4.3.1 Results of the Science Teachers' Interviews

As stated in the literature review, teachers play a key role in planning, implementing, and evaluating the teaching and learning process of students. In addition, giving them a dynamic role in curriculum development and implementation with proper training will lead to a successful implementation of such curriculum (RCD-PBL) (Keys and Bryan, 2001; Mantra, 2017; Tyler, 2013) and will equip them with the required competencies and skills, influence their perceptions and impact students' achievement (Badri et al. 2016; Konokman et al. 2017). Therefore, grasping their perceptions towards the RCD-PBL curriculum, challenges, involvement, training (professional development) and the effect of such curriculum on students' achievement and MAP scores are significantly important to be included as part of the current study. Hence, the interview entailed 21 questions divided into these six categories: RCD model, RCD-PBL impact and effectiveness, receptivity and challenges, involvement, professional development, and students' achievements. The interview transcripts generated from the recording were sent to the interviewee first and then read several times to become familiar with the data. Data were then coded using the interview research questions and the researchers' perspective. The researcher followed Braune and Clarke's thematic analysis process and used open coding as there were no preset codes. As the interview questions were divided into categories, the researcher examined interviewees' responses question by question and highlighted similar response statements using the same color, then to track its frequency, the software QDA MINER LITE v2.0.9 free edition was used. The interview transcript question (IQ), code, count, cases, and percentage of cases are shown in Table 69.

Table 69: Interview Transcript Questions, Count, Percentage Codes, Cases, and Percentage Cases

Interview transcript questions	Codes	Count	% Codes	Cases	% Cases
IQ1	Clear connection, progression, and alignment	6	3.20%	6	100%
	Deeper understanding	1	0.50%	1	17%
IQ2	PBL at the core of the curriculum	3	1.60%	3	50%
	Framework with a broad overview	3	1.60%	3	50%
	Scaffolding of knowledge and standards	3	1.60%	3	50%
	Proficiency in external examinations	1	0.50%	1	17%
IQ3	Yes/I believe/I am confident	6	3.20%	6	100%
IQ4	Student-centered learning	4	2.10%	4	67%
	Deeper understanding and higher levels of thinking	3	1.60%	3	50%
	Backward planning	1	0.50%	1	17%
	Identification of knowledge gaps and skills building	2	1.10%	2	33%
IQ5	Much impact	6	3.20%	6	100%
IQ6	Use of proper academic language	2	1.10%	2	33%
	Reflection	3	1.60%	3	50%
	Communicating orally, writing, or visually	1	0.50%	1	17%
	Knowledge transfer to unfamiliar situations	3	1.60%	3	50%
IQ7	Presentation to an audience	2	1.10%	2	33%
	Research skills	4	2.10%	4	67%
IQ8	Application in solving real-world problems and their connection	6	3.20%	6	100%
IQ9	Very effective	6	3.20%	6	100%
IQ10	To a large extent	5	2.60%	5	83%
IQ11	Pro-active learners/more involvement and participation	3	1.60%	3	50%
	Students had a voice and choice	3	1.60%	3	50%
	Collaboration and peer-tutoring	1	0.50%	1	17%
IQ12	Better perception	6	3.20%	6	100%
	Increased/ more confidence	5	2.60%	5	83%
IQ13	Components over cross and complement each other	2	1.10%	2	33%
	Integration of NGSS and MYP together and PBL implementation	2	1.10%	2	33%
	Student engagement	3	1.60%	3	50%
	Solving real-world problems	2	1.10%	2	33%

	Creativity and packaging knowledge into one product	3	1.60%	3	50%
IQ14	More relevant	6	3.20%	6	100%
IQ15	Higher levels of thinking and analysis required	2	1.10%	2	33%
	Planning differential learning activities together	2	1.10%	2	33%
	Planning and writing appropriate performance tasks	1	0.50%	1	17%
	Changing the routines and mindset of students	2	1.10%	2	33%
	Fear and reluctance	2	1.10%	2	33%
	Time management	2	1.10%	2	33%
	Letting go of students	1	0.50%	1	17%
	Changing teaching methodology	3	1.60%	3	50%
	Students and parents not ready	2	1.10%	2	33%
	Reverting back to the old teaching and learning ways	3	1.60%	3	50%
IQ16	Presence of PBL elements and scaffolding well before students' tasks	1	0.50%	1	17%
	Better understanding of PBL	3	1.60%	3	50%
	Transfer of concepts to real-life applications	1	0.50%	1	17%
	Higher levels of thinking, analysis, evaluation, and construction	1	0.50%	1	17%
	Reduction in time to plan differentiated learning tasks	1	0.50%	1	17%
	Writing standards-based student formative and summative assessments	2	1.10%	2	33%
	Writing and developing GRASPS tasks that meet the standards	1	0.50%	1	17%
	Planning, engaging, and giving relevant learning activities	1	0.50%	1	17%
IQ17	Unpacking standards and setting assessments	6	3.20%	6	100%
	Seeing the connection between developing GRASPS tasks	1	0.50%	1	17%
IQ18	Competence and knowledge in the subject area	5	2.60%	5	83%
	Higher confidence	3	1.60%	3	50%
	Adjustment and flexibility	3	1.60%	3	50%
IQ19	Large/significant extent (collaboration, involvement)	6	3.20%	6	100%
IQ20	Vertical/horizontal alignment embedded in the units	1	0.50%	1	17%
	Unit planners and assessment preliminary planned	5	2.60%	5	83%
IQ21	Improvement in MAP scores	6	3.20%	6	100%
IQ21a	Pedagogical implementation of RCD-PBL	2	1.10%	2	33%
	Examinations during Ramadan	1	0.50%	1	17%
	English as a second language/Language barrier	1	0.50%	1	17%
	Lack of parental involvement and support	2	1.10%	2	33%
	How skills and knowledge were acquired	1	0.50%	1	17%
IQ21b	Parental involvement	4	2.10%	4	67%
	More support from the administration	2	1.10%	2	33%
	Grade-level curriculum unit reflection as a whole team	1	0.50%	1	17%
	CPD to support the implementation process	1	0.50%	1	17%

	Teaching English inside science	1	0.50%	1	17%
	Administration, teachers, and parents working together	1	0.50%	1	17%
	Building efficacy of teachers	1	0.50%	1	17%

This section will demonstrate the science middle school teacher's perception regarding each interview category and its corresponding questions by referring to the transcripts and Table 60 major codes and percentages.

Section 1- RCD Model

This section entails the first three interview questions related to the alignment, readiness of the students for international exams, and effectiveness of the framework in developing a high-quality curriculum.

Q1: How did the steps offered by the RCD framework help you understand the alignment between standards, instructions, and assessment?

All of the middle school science teachers confirmed that the RCD framework provided a broad view and practical step-by-step comprehensive roadmap that helped them clearly understand the connection and alignment between the standards, instructions, and assessment. In addition, some have mentioned the importance of the RCD in having guidelines and combining all the required steps to designing a rigorous curriculum.

The results of the teachers' perceptions of the RCD-PBL framework show that all of the respondents have positive perceptions towards the RCD-PBL framework, and their comments revealed a nuanced view. Respondent 6 shared,

“The steps were practical instruction that shows how and where to start, to connect the standards expectations to teaching and learning, how to deliver them and assess them.”

Respondent 5 reflected

“RCD is a framework that guided us, through a checklist, to the development of a curriculum that allowed us to reach a deeper understanding of the alignment between standards, instructions, and assessment which led to more rigorous outcomes and unit assessment.

Respondent 1 put forward,

“As teachers, whenever we want to teach common core, and NGSS we have bits and pieces everywhere towards the steps we need to take when we design a unit of inquiry, lesson plan, or an assessment. The importance of the RCD for me is that it combined all the processes from A to Z that a teacher needs to do Step by step in order to be able to design a rigorous curriculum. Starting with the clustering of standards to unpacking the priority standards, then clustering them according to units of inquiry, looking at the big ideas, and understanding the cluster then helped us to gather them in a way that students can relate to and understand as well as how they can be transmitted to other subject areas.”

Respondent 4 reflected,

“The RCD gave us a broad view of steps that we need to do not necessarily in a linear way but guide us through steps that we need starting with the standards and ending up with the reflection. It is an ongoing cycle. Once we had that understanding that curriculum is a live document that keeps on changing to meet the students’ needs and school context. It gave us that guideline that was missed in any other curriculum development model we have been exposed too before.”

Respondent 3 reported,

“RCD is a very comprehensive roadmap that made us for once feel like curriculum developers and actually understand how to write and set performance tasks that are aligned to clear learning outcomes unpacked from the standards which helped us set our rubrics and plan engaging learning experiences through the uses of effective instructional strategies in order to make the learning experience relevant to all students”.

Other has highlighted the importance of using such a framework in setting relevant performance task assessment (project), driving core of the unit, that reflects the level of the standards along with needed formatives that allow students to reach the level expected.

Respondent 2 shared,

“The RCD helped us to have a deeper understanding of the standards and the way they are clustered in order to be able to set and develop an aligned assessment that meets the expectations of these standards. As previously we might have been teaching the standards, however, we did not understand the requirement and expectations of each one is the assessment either was not fully aligned with the standards or not rigorous enough to meet the DOK level offered by the standard. Such a roadmap did not only help us as teachers formulate the project that was the driving core of each unit but helped us as well set the formative that leads up and adds up to the performance task.”

Respondent 4 added,

“It provided us with an overall organizational plan that meets the diverse needs of the students and allowed them to achieve the desired learning outcomes through an authentic and relevant assessment that drives the units and allows us as teachers to be able to assess our students’ knowledge and skills.”

Additionally, some teachers affirmed that the framework has helped ensure vertical and horizontal articulation through scaffolding of knowledge and standards which helped them to identify gaps.

Respondent 6 said the steps,

“...allowed us to explore the standards by breaking them down, we looked at different knowledge such as procedural, etc. By understanding all aspects of what the standard would be addressing we were not only able to design the varied assessments to determine students’ proficiency, but we were also able to design the learning engagements and the pacing, determine the prerequisite knowledge to create tools to determine student status, formative assessments and determine the cross-curricular links with mathematics and English as well as find the alignment between the standards and the IB framework. It also provided a clear picture for both vertical and horizontal alignment which allowed us to identify gaps.”

Q2: How do you think this framework has helped ensure the vertical and horizontal articulation needed to prepare the students for the international exams and workforce?

While more than half of the middle school teachers have highlighted the importance of the holistic broad overview that the RCD offers to ensure vertical and horizontal articulation and prepare students for international assessments, others have highlighted how such framework ensures students' readiness for external exams based on mapping, clustering, and scaffolding standards while ensuring units and topics alignments from middle to high school. Mapping and clustering the standards allowed teachers to understand the success criteria and outcomes needed for students to reach the desired outcome and pass the expected grade level/cycle requirements.

Respondent 5 shared,

“The Framework prepares students for external exams. It is a comprehensive roadmap that is set after looking over the progression of the standards from middle school to high school. In addition, it is monitored, and reflected on continuously throughout the school year. Finally, having PBL as its core, the performance tasks help students relate to their environment, be more involved and engaged in the learning process, apply their knowledge and gain necessary skills such as thinking critically to solve problems, problem-solving, communications, etc..”

Respondent 3 explained,

“ Every international assessment focuses and assesses students on based on a certain age or year group, doing this RCD holistic view, you will be capable of aligning these topics into your units and placing them in a way that ensures students' readiness.”

Respondent 6 reported,

“I do believe that choosing the priority standards can be based on the course Leverage criteria which is the crossover application within the content alignment to external exams, and the Endurance criteria that is lasting beyond one grade.”

Respondent 2 shared,

“When you take a look at all the standards and you cluster them according to units based on each cycle, you will have the big picture, the end products from the standards (aim) by the end of the year whereby a set of knowledge and skills need to be grasped in each grade level and how are we scaffolding and building these units accordingly as well taking into consideration the students pre-requisite, either from the previous unit or the years before, so it gave us that purpose of scaffolding and vertical articulation from the beginning.”

Moreover, teachers have mentioned how such framework ensured the articulation vertically and horizontally by minimizing the gaps by building skills and scaffolding the knowledge as the RCD incorporated the backward design model. In addition, how the RCD provided a foundation upon which all other requirements could be incorporated, aligned, and monitored.

Respondents 4 and 2 respectively stated,

“Beginning with the end in mind (backward design process within the RCD) is something very important as you will be able to know the outcomes, what students be able to do and know by the end of each grade level or cycle. Therefore, mapping, clustering, and scaffolding the standards will ensure vertical and horizontal alignment within the science curriculum and allow the students to reach the desired outcome taking into consideration their prior knowledge.”

“ With the end in mind, mapping out the K-12 standards, clustering them between priority and supporting, embedding them in a unit, taking into consideration the objectives, topics, focus of certain international assessment and doing the scope and pacing has given the broad overview of the horizontal and vertical articulation whereby the gaps were addressed, skills were built, and knowledge was scaffolded to prepare students for success.”

Finally, while all respondents were able of highlighting how the RCD framework ensured vertical and horizontal articulation and prepared students for international assessment, one teacher (respondent 5) suggested the incorporation of additional field trips and interactions with professionals to strengthen the horizontal articulation to prepare students for the workforce.

Q3: Do you believe that the RCD process results in the development of high-quality curriculum units?

All interviewees believed that the RCD process led to the development of high-quality curriculum units due to the strong alignment between standards, instructions, and assessment. They have stressed on the importance of their involvement and collaboration with experts and curriculum developers that RCD brings together as a factor that leads to building a high-quality curriculum. Moreover, the interviewees mentioned the power of ongoing feedback provided throughout the process and the importance of having experts building capacity in the team.

Respondent 2 said,

“I believe that RCD results in the development of high-quality curriculum as it impacts first on teachers’ understanding and secondly on the quality of the units produced. We now have a deeper understanding of how to teach the standards and align them to our instructions and assessment rather than choosing a specific content and delivering it to students. We are currently more capable of determining the skills that students have to learn by the end of a cycle or grade level through relevant units of inquiry”.

Respondent 3 shared,

“I am confident that it leads to high-quality curriculum development, specifically after reflecting back on our units written based on the RCD-PBL, these units were more aligned, meeting the international standards of writing units because they had all the components needed for developing a quality curriculum whereby we as teachers have a comprehensive checklist that allowed us to construct these units as a team to ensure a proper alignment between standards, instructions, learning experience, and assessment and receive constructive feedback from RCD leader and curriculum developer which lead to higher quality curriculum that is relevant to the context where our students live.”

Respondent 1 reported,

“ Our buy-in, contribution, and collaboration in this process with the experts have raised our level of understanding which leads to a higher level of curriculum that is meeting not only the school but the regional context as well.”

Respondent 4 stated,

“Yes, I do believe that high-quality curriculum units are developed through RCD since it starts by identifying the priority standards and matching all the important components as I mentioned before like the teachable concepts and skills from the “unwrapped” Priority Standards and a series of related standards-based performance tasks, that progressively develop and reveal student understanding based on the foundational concepts to more complex skills.”

Respondent 5 said,

“The RCD process does produce high-quality curriculum units when there is sufficient collaboration amongst the creators who can sharpen each other’s ideas and pool together various resources to enhance the planner.”

In addition, they have expressed the importance of understanding the process, including its components and purpose as a crucial factor that influences the development of such a curriculum. Along with monitoring and setting proper quality control protocols in place, as human factors will affect how the process is implemented.

Respondent 6 reflected,

“RCD does lead to the development of high-quality curriculum units; however, it is critical that those involved understand the process – components and purpose. There is a human factor present that will impact the implementation of the process if quality control protocols are not in place.”

According to the previous viewpoints. All the participating science teachers indicated and confirmed that the RCD led to the development of a high-quality curriculum.

Based on the first three interview questions related to the RCD model, and looking at the codes extracted from these questions, the following was the first theme generated “The RCD model framework can help in understanding the standards, instructions, and assessments, ensuring vertical and horizontal articulation and development of high-quality curricula in science”.

Section 2- RCD-PBL Units Impact and benefits

This section encompasses eight questions (Q4-Q11) all related to the impact of RCD-PBL on planning and teaching methods in comparison to textbook-based curricula, the impact of PBL assessment on students' engagement, the effectiveness of such curriculum in teaching and learning science, next to the benefits of the GRASPS assessment in terms of igniting students' interest and curiosity in the science, how much authentic and relevant assessment allowed students to demonstrate and transfer their knowledge and skills in a real-life application.

With regards to codes and percentages generated from the second section of the interview questions "impact and benefits of RCD-PBL curriculum units", 67 % stated that they are student-centered; are more engaging (100%); they enable student reflection (50%), improve communication skills (17%); promote the use of proper academic language (33%); and allow knowledge transfer to unfamiliar situations (50%). In addition, PBL assessment in the units allowed students to demonstrate their competencies by presenting to an audience (33%); using their research skills (67%) in solving real-world problems using scientific concepts (100%). Respondents believed the PBL approach is very effective (100%), it increases students' interest and curiosity in science to a large extent (83%) as it allows students to have a voice and choice (50%), allows more involvement and participation (50%), and promotes collaboration and peer tutoring (17%).

Q4: How have RCD-PBL units affected your planning and teaching methods compared to textbook-based curricula planning?

Looking over the interview transcripts, half of the middle school teachers mentioned that RCD-PBL units brought continuity and resulted in a deeper understanding of PBL. The way the units were developed and designed, endorsed and enhanced real-life connection from the standards to the students which was reflected in their teaching method and planning. Moreover, 67% of the interviewees have highlighted how their teaching methods have shifted from teacher-centered (lecturing) to a student-centered learning approach which led to higher-order and critical thinking skills.

Respondent 6 stated,

"I understand the standards more deeply and am able to adapt depending on the students in front of me; there is more agency in the process than being told to teach a textbook from cover to cover without understanding how the components fit together."

Respondent 5 put forward,

“The RCD PBL units have helped to bring continuity to the units, so students see use in the information long-term therefore, my planning has shifted from me as a lead person to me being a facilitator of knowledge that plans to start with the end in mind (backward planning) and the standards.”

Respondent 4 reported,

“The RCD units give me a deep understanding of what will be taught, how, for what purpose, and for how long. My teaching and planning went from lecturing to guided and open inquiry. From worksheets to group work and peer work and projects. Moving from teacher-centered activities to student-centered. From teaching from a textbook one size fits all with some support to special needs students towards authentic, meaningful, and relevant projects that for which the lesson revolves around.”

In addition, some of the interviewees have mentioned how their planning is now based on the skills and concepts, synthesized from the standards, that need to be taught.

Respondent 1 stated,

“My planning shifted from only relying on content to what skills my students need to acquire and how the content is delivered through acquiring and building those skills.”

Respondent 2 reported,

“At first it took me a while to understand the word learning in PBL which is not such a tool that leads to a project or product at the end of a unit. It is a journey that allows students to grow, to learn the usage and application of their learning outside my classroom wall. Therefore, my planning shifted, and more students were focused and involved in the learning process, I considered the skills and concepts that need to be taught, what kind of gap might I face, and how will I facilitate the learning for students.”

Finally, some have highlighted that when the planning revolved around students and involved them in the learning process, the classroom became more active and purposeful.

Respondent 1 said,

“My teaching method and planning have changed from a teacher-centered to a student-centered inquiry-based environment. Although it has been a bit challenging for me at first to get rid of my old habits, after involving my lessons around students, hearing their questions, and discussions, and allowing them to come up with their own solutions made my lessons more alive and purposeful especially adding the reflection part in the process made my planning became a learning journey rather than a course.”

Respondent 3 reflected,

“I learned more to let go and listen and involve students in the lesson. Letting go allowed me more time to address and support groups that needed and scaffold the learning for others. It created an engaging and purposeful environment that allows everyone to learn”.

Q5: What impact do project-based learning assessments have on students’ engagement?

All middle school science teachers have mentioned that PBL assessments had increased students’ engagement as the tasks gave purpose to the learning by being relevant, authentic, and contextual.

Respondent 1 stated,

“PBL assessment embedded in the RCD were relevant and authentic, Therefore, I would say a huge deal because it gives purpose for the learning. I have found this type of learning takes on a life of its own and students learn the content, skills, etc. because these are tools that help them achieve the purpose; the content and skills are not a goal in themselves which can be boring. Context is critical to engagement.”

Respondent 5 put forward,

“The students find these assessments to be more engaging than the typical exam. Due to these assessments typically being research-based, contextual, and authentic, therefore, it enlightens the students and allows them to understand how to apply their knowledge and understanding in addressing the task (problem) they are facing in their society.”

Respondent 6 said,

“PBL assessments have placed students in realistic, contextualized, problem-solving environments. These projects are served to connect between phenomena in the classroom and real-life experiences. It gave students ownership over their learning and gave them the liberty to choose their way to demonstrate their understanding and skills and the type of product they will produce at the end; therefore, they were more engaged and motivated to complete the given task compared to traditional exam.”

Respondent 4 reported,

“I saw an increased level of engagement from my students as they were allowed to express themselves, I started to differentiate differently moving from higher, mid, and low-level students, differentiation is happening along the way in the assessment, how they chose to approach and solve the problem, in their planning, their choice of products, their interest, etc.. which lead to higher engagement, especially that the PBL performance tasks were taken from their surrounding environment and context, so they felt the need and urge to address them and be part of their resolution.”

One teacher went even deeper in the response and explained that engagement depends on students’ multiple intelligences and that the level of engagement varied based on students’ perceptions and interests. In addition, it was mentioned that giving the students the choice to decide how they want to present their product has offered them the opportunity to shine and increased their engagement in their learning process.

Respondent 2 reported that,

“Students’ engagement depends on students’ multiple intelligence while there is a different level of engagement that depends on students’ interest and perceptions e.g. Some students (visual students) chose to do a poster as a product for a certain grasped tasks while others preferred to write an essay or produced a 3D model. So, the multiple types of products offered to students have given them a better way to shine and engage in the learning process.”

Furthermore, another teacher has highlighted the importance of being patriotic, especially for Emirati students, whereby the urge of being effective members of their community and address the contextualized PBL assessment has increased their involvement and engagement.

Respondent 3 reflected,

“Contextualizing PBL assessment, especially since our students are Emiratis, they are patriotic, they feel the urge of taking part and finding a solution and being effective members of the community has increased their involvement and engagement in learning especially since they needed to present their outcomes with effective members based on the audience set.”

Q6: How did the final product enable students to demonstrate their knowledge and understanding of the science concepts taught within each unit of inquiry?

The middle school teachers have highlighted how students were able to demonstrate their knowledge and understanding of science concepts in writing, oral, or visual form and by questioning, exploring, explaining, evaluating, and reflecting on planning and knowledge construction through engagement in authentic, real-life problems which allowed them to link and transfer their prior knowledge and experience to the new situations. In addition, knowledge could be assessed through the use of IB rubrics, students’ journal, and use of appropriate academic language.

Respondent 1 explained,

“It allowed students in creating, questioning, revising, and constructing knowledge through engagement in authentic, real-life problems. It allowed them to link their prior knowledge and experience to the new situation which made the learning process more relevant and meaningful.”

Respondent 2 shared that,

“All projects were rated based on criteria whether A knowledge and understanding, B planning, C analyzing and D research skills whereby PBL units developed using the RCD incorporated the IB MYP components. So for e.g using proper academic language, using and applying their scientific knowledge appropriately, and showcasing how they were capable of relating the concepts taught within the unit to the phenomena that they are addressing all showcased the knowledge acquired.”

Respondent 3 reflected,

“...students provide feedback by asking them to keep a project journal evaluate themselves using the project rubric and answer additional self-assessment questions. Reflection helps students relate their new knowledge to their prior understanding and understand how their learning and problem-solving strategies might be reapplied. It gives students a means to determine what they think they have learned and how well they have learned it. Rubrics have helped to evaluate how successfully students address specific goals and performances.”

Respondent 4 reported,

“...The unit GRASP allowed them to present and transfer their knowledge into unfamiliar situations. By using a proper academic vocabulary to communicate and reflect on their understanding.”

Respondent 5 put forward,

“The students were able to communicate their understanding in written form, orally or visually and I think this added depth to their understanding of the topics.”

Respondent 6 stated,

“They had to take all they learned and apply it in an unfamiliar context.”

Q7: How did the final product allow students to demonstrate their competence in the essential skill set for each unit of inquiry project?

All middle school science teachers interviewed, have mentioned that the skills are embedded in the assessment design and rubric whereby the success of students in completing the task and presenting a product relies on the required effective skills that need to be used. The common skills that teachers highlighted in the interview were research skills, communications skills, oral skills (presentation to an audience), and thinking skills. All reflecting on the integral components of the PBL framework.

Respondent 4 reported,

“The product shows the students’ outcomes as they demonstrated these competencies based on the skills needed and gave them chance to reflect by following certain criteria.”

Respondent 5 explained that,

“...the rubrics always endure that every part of the task is connected to a standard that needs to be completed by demonstrating a certain skill.

Respondent 6 put forward,

“.....these skills are embedded in the design of the assessment and necessary for their success in completing it up to expectations.”

Respondent 2 reported,

“Depends on the skills that each authentic performance task required to reach its success for e.g research skills: the way the students write the report, clearly communicate information using scientific language, effectively cite reliable resources referred to or for e.g conducting investigation and manipulating variables whether on hand or virtually and writing up a lab report and making sure that all the scientific investigation elements are properly stated and addressed.”

Respondent 3 shared,

“Every performance task done needs some common skills, to begin with, such as research skills, moving from one unit to another the quality of the product increase as skills were developed and focused on more in the lessons e.g students research skills were seen based on how they take notes and how to find credible sources, how to properly cite their information, how to communicate the information using scientific language.”

Respondent 1 explained,

“The final product reflected their journey towards reaching the desired outcome where several skills were used by students whether research, communication, critical thinking, creative thinking, etc.. coming and presenting with confidence their work to an audience

allows them to reflect on the process as well as make sure the keywords (action verbs) found within the rubric and standards are reached. In addition, such direct involvement gives them an appreciation of the wide range of approaches that are used to investigate, model, and explain the world.”

Q8: How did the final product enable students to understand the relationship between the broad scientific concepts of the unit and the real-world problems?

All middle school science teachers emphasized how involving students in taking up a role in a scenario has given them the real and broader aspect of the application of their knowledge and skills outside classroom walls. In addition, teachers have highlighted how involving students in such assessments (GRASPS) allowed them to draw connections between different concepts and allowed them to see how and where their knowledge and skills can be put into action.

Respondent 3 reflected,

“It makes the explicit link to the outside world. e.g. as environmental engineering, the students were asked to propose a simple solution to address the existing environmental issues specifically marine while contextualizing it in UAE (whether they have visited or watched it). The topic was adaptation. They have referred to the factors that influence the adaptation of certain species, research other impacts, etc..”.

Respondent 6 stated,

“It makes the explicit link. What is critical is their reflective process before during and after so that they can synthesize their learning.”

Respondent 1 explained,

“Transferring the knowledge and skills by taking a role in the task that reflects the actual role that they will play in the workforce allows students to understand why they are learning these concepts and how and where these concepts are put into action. E.g Engaging in the practices of engineering has helped students understand the work of engineers and the links between engineering and science. Taking part in these practices made students’ knowledge more meaningful and relevant.”

Respondent 2 shared,

“Involving students in GRASPS tasks, whereby they were given a role and scenario allowed them to see how scientific concepts can be transferred and used outside the classroom walls. Working in groups and coming up with creative ideas in terms of solving or addressing a specific issue and presenting the product to an authentic audience whether orally, through a model or any other means showed how students were competent, confident, and proud of their work. As well it shows how they understood the connection and be able to perform such connection between what is learned, how it is learned, and how it is applied.”

Respondent 4 said,

“...PBL allows students not only to build confidence, collaborate with friends it increased their motivation and engagement in the task, acquired a high level of understanding of scientific concepts in real-world, enhanced their critical thinking and creative skills.”

Respondent 5 reported,

“My students became life smart. They were capable to stand and present with confidence their work in front of an audience whether taking up a role of a scientist, engineer, Meteorologist, etc.. and apply what they learn in a real-world setting showed the progression they have made and how they were capable to transfer their knowledge and skills beyond the classroom.”

Q9: How effective was the PBL approach to teaching and learning science?

According to the middle school science, teacher PBL was an effective approach to use in delivering science curriculum, although it was challenging for them at first to understand and apply such an approach, as it delivered the rigor and depth that the NGSS standards demand. In addition, teachers have highlighted how PBL created a higher engagement with the content and allowed students to reach deeper learning whereby they took on the role and became real engineers and scientists.

Respondent 1 reported,

“Through PBL, my students have understood the importance and the connection between science and other subjects. They were able to connect between science and math, and between science and English when they write a claim and a counterclaim. They looked at an article and analyzed it, annotated it. It had a huge effect on my way of teaching science and their way of learning sciences. Addressing the NGSS standards through PBL projects made the students reach the rigor expected in the content and allowed them to apply their knowledge in a real-life scenario.”

Respondent 2 shared,

“As students learn best by doing, PBL was an effective approach to be applied and used in science specifically because the rigor of the NGSS standards was achieved in an engaging and meaningful way throughout these PBL projects. Especially since Science is all about experimenting, observing, and analyzing concepts and data. This approach allowed students to deeper their thinking and apply their knowledge to new scenarios which increased student retention and motivation.”

Respondent 3 reflected,

“It helps improve the quality of learning by developing students’ reflective, critical and collaborative skills. Students’ reasoning skills improved through questioning and problem-solving. The benefit of PBL is that it restores students’ natural sense of ownership and creativity in science.”

Respondent 4 reported,

“Teaching using PBL allowed students not only to learn new concepts, but they had the chance to relate them to their real-life by taking up a role whether engineer, scientist, marine biologist, etc. This made learning more meaningful and engaging and enhanced their critical and creative skills.”

Respondent 5 put forward,

“I think it is the best approach to investigate real-world science questions and solve authentic challenges and problems. It helps students acquire needed skills through practice.”

Respondent 6 stated,

“...PBL is critical to both understanding the conceptual nature and being able to transfer that learning into different contexts.”

Q10: To what extent do you think that these conceptual/contextual projects (GRASPS) have increased students’ interest and curiosity in science?

GRASPS tasks have increased students’ interest and curiosity in science to a large extent as reported by most teachers.

Respondent 1 stated,

“The curiosity and interest have increased to a large extent when the GRASPS were used as an assessment instead of test based. All students felt involved and were given a choice based on their capabilities to showcase/select their product which allowed them to grow even more. They have started to see the application of learning. In addition, we could see that as well when they started to ask deeper thinking questions, research, and change their design accordingly which allowed them to learn how to transfer and use their knowledge and skills to the best potential to address the phenomena or problem they are working on.”

Respondent 2 shared,

“When a phenomenon is addressing a concept or more in a familiar context, the learning experience becomes more relevant and meaningful. The students will be more curious to try to dissect the GRASPS task, ask questions, research, plan, design, reflect on their design, come up with creative ideas, execute the product and present it to an authentic audience, this cycle leads to a gain of interest in science. These kinds of assessments

allowed students to see the application of knowledge and usage/gain of skills in a real-life application thus enhancing the critical and creative thinking process of our students”.

Respondent 3 explained that,

“Conceptual/contextual GRASPS projects encouraged researching and exploring new topics. It increased students’ interest and curiosity as it allowed them to add their personal experience, and practice ownership.

Respondent 4 shared,

“As most of the students were Emiratis, you can feel how interested and intuitive they became once they came to know that these GRASPS projects are based on their context. They felt the urge of contributing and helping their society to find a solution or come up with ideas and products which led to higher order thinking ideas, design, and solutions.”

Respondent 5 put forward, “Some students have found certain topics to be in line with what their current interests are and other students’ curiosity has been revved up due to these projects.”

In addition, one teacher (respondent 6) highlighted that while GRASPS largely impacts students’ interest and curiosity, it all depends on how the implementation was approached.

She has stated:

“I would say it depends on how the implementation was approached; was it approached in a manner that nurtures curiosity and interest or was it approached in a teacher-driven manner.”

Q11: How were the students interacting with such a curriculum whereby the design, approach, and assessment were different from what they were used to?

Initially, the curriculum was challenging for the students as advocated by all teachers. While some students easily adapted to the new design, approach, and assessment type than others,

things got easier as the implementation became more effective which led to higher engagement, collaboration, and more cognitive outcomes. In addition to being more proactive and more involved, students had a voice and choice in their learning process.

Respondent 6 stated,

“At first they struggled but as implementation became more effective and students had several opportunities to be exposed, they grew in confidence which led to stronger student engagement and more cognitively complex outcomes.”

Respondent 3 reflected,

“It was hard for them and us at the beginning as the routine, mindset, teaching methods, and assessment type were changed. They went from being passive receivers to active participants whereby everything revolved around them rather than us. They needed to have a voice through discussion, debates, etc... they needed to make choices whether as a group or as an individual this is something that they were not used to before. Some students were shy and reluctant at the beginning as they were afraid to share their ideas thinking it might be wrong.”

Respondent 5 put forward,

“It took them some time to get used to the fact that teaching and learning were relying more on them, enhancing their question type and style. Improve their thinking process. It was at first hard to understand that not everything is linked to a mark and that it is ok to research change and come up with and discuss ideas. It took them some time to understand that they could be more than one answer and approach and solution.”

Respondent 2 shared,

“It was challenging at first to change the routine of the students and their habits, and their involvement in the learning process, whereby more voices and choices were given to them that is something that they were not familiar with. Moving from teaching for a one-shot assessment to more learning through a project where they were given the choice of selecting the type of product sometimes that they will produce. It took some time for

them and myself to be able to let go and support and facilitate and explain how the process [sic]. Learning how to embrace, collaborate and peer tutor, each other was something additional they needed to learn and embrace too.”

Respondent 4 explained,

“It took them some time to let go of the old system whether they were learning for the marks and not for the sake of learning. It took them some time to understand that this is a safe environment to ask questions, and share ideas, it is not wrong or right answer and receive feedback. As the year progressed students understood the concepts of learning on their own, on applying and seeing how the new concepts are transferable and applicable in their real-life applications which led unconsciously to reaching higher attainments in standardized assessment.”

Respondent 1 explained,

“....convincing the students first and their parents about the importance of the process and the learning journey because PBL embedded in the curriculum is an effective teaching approach that allows students to be part of the learning process, to take initiative, to reflect, to ask, to communicate, etc. Thus, students will be able to reach the rigor and level expected in their tasks.”

Finally, looking over the second section of the questions addressed in the interview session, participants have indicated that RCD-PBL gave continuity to the units and provided the teacher with a deeper understanding of PBL. These curriculum units allowed students to participate in classroom activities and discussions actively and enthusiastically. PBL tasks were relevant, contextual, and authentic which made learning purposeful and increased students’ engagement. This engagement depends on students’ multiple intelligence and varies based on their perceptions and interests. Teacher planning is now based on skills and concepts extrapolated from the standards. Students can address higher-order and critical thinking questions as the teaching method and planning have shifted from a teacher-centered to a student-

centered approach. Through GRASPS tasks students' interest and curiosity increased to a significant extent. Throughout these authentic and contextual assessments, students could demonstrate their knowledge and skills in a variety of ways based on the product selected and be able to transfer and apply such knowledge and skills in unfamiliar and new situations. The product was assessed against a rubric that was based on effective skills and knowledge needed to be used to reach such a product. Furthermore, regardless of the challenges faced by the teacher at the beginning of the implementation, they believed that PBL was an effective approach to delivering science as the rigor of the NGSS standards was met and reached. Finally, while some students easily adapted to the new design, approach, and assessment type, the teacher had to help and support other students and their parents to outgrow the fear of marks. Based on the interviewees' responses and referring to thematic coding, the following theme was set "RCD-PBL units are student-centered, more engaging, build skills, allow knowledge transfer, and are an effective approach to teaching and learning science."

Section 3- Receptivity& Challenges

The third section encompasses three interview questions (Q12-Q14) that address teachers' receptivity of the RCD-PBL in terms of relevancy compared to textbook curriculum, likability features, confidence and perceptions change throughout the implementation. In addition to one question (Q14) that addressed the hindrance and difficulties encountered by teachers.

Q12: How has your perception and confidence of PBL evolved since first encountering the instructional model?

On receptivity, most responses from the interview questions show that the perception has changed for the better and the confidence levels have increased for PBL.

Respondent 1 explained that their perception did not change but has actually grown:

"My understanding of PBL has, not changed, but grew as I moved forward in the units. The more I understood it and properly implement it the higher was its impact on my students and on me as a teacher."

Respondent 2 shared,

“My perception has changed from seeing the project (GRASPS) as a final assessment to a tool for learning throughout the unit. As the units progressed my confidence in the implementation has increased.”

Respondent 3 reflected,

“At first It was difficult to keep momentum. I was concerned also about time especially at the beginning of this process, wondering about what means to guide and support students in their first project. However, this saving of time was then increased when teaching the PBL units for the second semester. I was more confident in delivering such curriculum as we progressed through the year, especially when students started to understand the design and approach adopted in this revamped curriculum.”

Respondent 4 put forward,

“As the first time, it was a big challenge but with the training and collaborative work, things become clearer and easier. I was hesitant at first if I was going to succeed, how will I implement this properly, and how I involved my students in but with the help of the admin, training sessions, and support things got easier in every unit. Furthermore, the thing that stuck out the most was thinking about the project as a tool for learning as opposed to thinking about it as something you do at the end as a final assessment.”

Respondent 5 shared,

“The first time, I wasn’t very sure that I can deliver the PBL units. After the completion of one unit, I had a better understanding and found joy in getting the opportunity like this in the classroom.”

Respondent 6 said,

“I have always been a believer in this approach as I saw how it not only created a buzz inside the classroom but beyond into the school community.”

Q13: what did you like the most about these RCD-PBL science units?

Regarding the PBL units, the respondents mainly liked the student engagement part; solving real-world problems; the integration between NGSS and MYP together with PBL implementation; creativity, and packaging knowledge into one product, and that components over cross and complement each other.

Respondent 1 said,

“I like how the fact that PBL was centralized in the curriculum, whereby everything revolved around the performance task (GRASPS). The rigor of the standards was met throughout this project, students need were addressed whereby students had a voice and choice, asked questions, and came up with various solutions or product, they were more open, and more engaged than before, reflecting back on their work made improve their decisions and thinking process.”

Respondent 2 shared,

The connection between RCD, PBL, and IB was phenomenal to see. Seeing and being part of how to use the roadmap to align the Next-generation Science standards that are delivered and assessed through PBL whereby the phenomena chosen revolved around the inquiry cycle that is highlighted in the IB program was impressive. Another thing is the formative set around and leads up to the GRASPS task was efficient, especially since we were given feedback to students along the process.”

Respondent 3 mentioned,

“We went from a normal, traditional classroom to a creative, engaging, problem-solving, and inquiry-based classroom. I can use my creativity in creating these unique experiences for my students, for which they will be using their creativity and skills to deliver a product that will showcase their knowledge and understanding.”

Respondent 4 reported,

“Seeing students being lifelong learners was something worth applying and implementing. Students mature throughout these projects. They became more self-

directed, more aware of life outside the classroom, and more engaged in their learning. They were actually becoming problem solvers.”

Respondent 5 put forward,

“I enjoy the element of creativity and how students could combine knowledge gained from the lessons, peripheral knowledge from research sources, and their interests into one final product.”

Respondent 6 stated,

“I like the fact that they are visibly thoughtful about alignment and development as well as the fact we reflect on them before during and after and improve them every year.”

Q13: How relevant were these RCD-PBL science units compared to the textbook curriculum?

As compared to the textbook curriculum, all six respondents affirmed that RCD-PBL science units are more relevant, but respondent 5 was cautious as they mentioned that the RCD-PBL science units are relevant to particular students it was designed for, in this case students in Abu Dhabi, UAE.

Respondent 1 explained,

“...while building these units, my students, their context, and meeting their needs were the major things I was aiming for to make the learning more accessible and meaningful to all without dumping the level of the standards or jeopardizing the knowledge and skills that need to acquire.”

Respondent 2 shared,

“A textbook is basically one size fits all however, while scientific concepts cannot change, the approach, learning experiences, and context where they are being delivered varies and that is what RCD-PBL focused on. These science units still delivered the same NGSS standards however, the approach and framework used were more authentic, relevant, and contextual to our students.”

Respondent 3 reflected,

“Textbooks are resources that we can refer to for content inquiry, however, the delivery of this content must take into consideration, students’ prior knowledge, the culture, context, and interest of the students that is what the RCD-PBL offer a meaningful, contextual and authentic classroom experiences and tasks that are relevant to students rather than one size fits all.”

Respondent 4 reported,

“RCD-PBL is more relevant as the units show rigor in their pedagogy and they prepare students for different internal and external examinations, as well as to be able to perform at high levels of Bloom's taxonomy.”

Respondent 5 put forward,

“I believe the RCD PBLs were definitely more designed towards the student population here at my school compared to...back home. If these textbooks were adopted for the students in this particular context or any study from a different environment, values, and context it would be somewhat of a disservice to the things happening in the student population and their current world they live in.”

Respondent 6 stated,

“I would say it depends on the textbook design but in general I would say it’s much more relevant because it’s designed to go beyond the textbook–content–only approach.”

Q14: What hindrances and difficulties did you encounter as you attempted to implement these units?

Respondents highlighted that they all faced hindrances and difficulties as they attempted to implement the PBL units, such as changing parents' perceptions about assessment type, difficulty in changing the routines and mindset of students; higher levels of thinking and analysis required; planning differential learning activities together; fear and reluctance; time

management; letting go of students; changing teaching methodology and reverting back to the old teaching and learning ways.

Respondent 1 reflected,

“It was challenging working with other teachers who weren’t as engaged or interested in the process; they just wanted to go back to their topical suitcase curriculum approach. There was some negativity around the time invested as well as the paperwork required which to me doesn’t make sense; good planning takes time and effort and it’s a crucial part of our job.”

Respondent 2 said,

“While time and pacing were challenging as we implemented the units, one of the difficulties I have to say was finding the best way to execute a blended learning or distance learning curriculum without reverting to the previous method of instruction.”

Respondent 3 shared,

“One of the biggest challenges was changing students’ routines and mindsets about the assessment and learning process. It took me some time to understand how to deliver these units, how to provide the required support how to increase students' reasoning skills, and how to help and guide them to understand this type of assessment. This was addressed because we have a supporting coach and coordinator that always followed up and monitored the learning process by supporting us and the students.”

Respondent 4 reported,

“The challenge I faced at the start of the implementation process was changing students’ routines and mindsets about the assessment and learning process. Having parents’ involvement and understanding such curriculum has helped in addressing this challenge although took some time to observe such change occur.”

Respondent 5 put forward,

“It was hard at first to find the proper way to guide, deliver and explain projects for students that embodied true PBL. Managing time as setting routines and changing students’ approach about assessment took time. Getting used to letting go and not

lecturing and providing the answer or going back to the old way was another challenge. I always had to go back to my coach and our team for support. It got easier in time as the required support and help needed were always there. Regular meeting with coordinator to address challenges, support, monitor the process, check on students' progress."

Respondent 6 stated,

"Parents and leadership were unsure because the focus is on grades – the sign of a good teacher is everyone gets 90%+ but inflated grades are not an indication of learning. This is an ongoing challenge as the culture of a place doesn't change overnight and there is always a fear of the new and unknown. Students were more flexible as they were building their confidence, skills, knowledge, etc. with the teacher as a coach. It was a stronger partnership there."

While respondents have faced several and sometimes similar challenges, they all have highlighted the importance of the support they have gotten from their coaches and coordinators to overcome them. In addition, some have highlighted the importance of parents' involvement and support in this process. Furthermore, changing the parents' perspectives will help their children adjust must faster. Finally, looking at the code generated under this section, the third theme synthesized was "Despite certain challenges, RCD-PBL is more relevant than the textbook curricula".

Section 4- Professional Development

In terms of professional development and competencies, this section included three interview questions (Q15-Q17) related to the RCD/PBL, and NGSS training for which teachers attended. In addition, to the importance of teacher competencies in the development and implementation process.

For Q15: How did the RCD/PBL training help you in developing and implementing these PBL units of study?

The teachers' perceptions were positive and showed that all respondents viewed the RCD-PBL training as important and helpful in the development and implementation of PBL units of study.

Respondent 1 shared,

“...The discussion and coaching were very important in all these sessions. They provided the guidance, support, and feedback we need to be able to properly develop and implement these units. In addition, we saw the importance of sharing and embedding our inputs, reflections, and judgment while developing these units. So, we had more than 7 training sessions.... importance of the process.... using the RCD framework model to develop units.... authentic assessment training, ... centralizing the curriculum units around PBS,...writing rubrics and success criteria training, ... giving and receiving meaningful feedback”

Respondent 2 explained,

“The training has upskilled us and supported us whether in the development and how the best way to approach and implement it. It helped us understand the importance of the alignment and connection between all the components. It actually highlighted the importance of our roles as educators, and influencers of learning as the success of the implementation will rely in a big part on us.”

Respondent 3 reported,

“RCD training provided us with a better understanding of the meaning of PBL...help us improve the quality of learning by developing deep thinking skills such as analyzing and evaluating information and constructing a solution from a variety of sources helping students to see how the new concepts are transferable and applicable in their real-life applications.”

Respondent 4 stated,

“RCD training played a vital role in shaping our understanding of the importance of building and implementing rigor units to teach science. It helped reduce the time to plan

differentiated learning tasks that helped in scaffolding the learning for the students and allowed them to move from the Zone of Proximal Development level with the help of us as instructors and their colleagues through group work. This training showcased and reinforced my strengths in ...planning, engaging, and relevant learning activities, writing standards-based student formative and summative assessments, writing and developing GRASPS tasks that meet the standards.”

Respondent 5 said,

“RCD training helped us to make sure the elements needed for the PBL were present and scaffolded well before students would have to exercise their independence on the task.”

Respondent 6 put forward,

“It provided a basis on which we carried conversations forward to develop the units and get feedback both from students and teachers. It’s an ongoing process where we always reflect and improve.”

To conclude, the interviewees indicated that RCD-PBL training helped them in developing and implementing the PBL units of study in the following ways: the presence of PBL elements and scaffolding well before students' tasks; better understanding of PBL; transfer of concepts to real-life applications; higher levels of thinking, analysis, evaluation, and construction; reduction in time to plan differentiated learning tasks; writing standards-based student formative and summative assessments; writing and developing GRASPS tasks that meet the standards; planning, engaging and giving relevant learning activities.

As for Q16: How did the NGSS training sessions help you develop assessments that tackle the performance expectation observable features?

According to all the respondents, the NGSS training unpacked the standards and highlighted how to set assessments that address the standards. This is important since a standard is more easily translated into the unit and daily lesson plans after being unwrapped or unpacked. This

method aids teachers in focusing on what is crucial for instruction. For planning, the unpacked standard should be adequate. Respondent 1 shared,

“...when you unpack that standard and understand what are the skills and the knowledge, what is the cross-cutting concept, what is the engineering standards that go with it and support it more, ... the more we could create that PBL at the end because we understood the standards, we understood the expectations to what extent do we need to teach the standards, to what level ... they told us how to look at even the assessment expectations, what to assess and what not to assess, that was really helpful and eye-opening for us to understand when we build that PBL, where do I need to stop? To what depth do I need to tackle this information? And how and where do I assess it?”

Respondent 2 explained,

“It helped us unpack and dissect the standards and highlight what students need to know and be able to do and highlighted how to set assessments that address the standards.”

Respondent 3 reported,

“The NGSS training provided opportunities for teachers to observe and record evidence of students’ learning such as developing and refining models; generating, discussing, and analyzing data; engaging in both spoken and written explanations and argumentation and reflecting on their understanding. Such an opportunity was important in the development of assessments of three-dimensional science learning. It shows us how students will need multiple and varied assessment opportunities to demonstrate their competence on the performance expectations.”

Respondent 4 stated,

“NGSS training helped to unpack the standards and deeply understand what each standard requires us to teach students and what success criteria look like.... The training sessions have also helped us in linking the concepts and practices so that we can develop varied assessment opportunities to demonstrate and meet students’ proficiencies.”

Respondent 5 said,

“It helped me understand how to read the standard, and how to set up an assessment that addresses the standards by looking at the observable features that each standard offers. It made me see the connection between developing GRASPS tasks whereby the success criteria and rubric are based on the standards.”

Respondent 6 put forward,

“It helped me understand how NGSS works and how to use the documentation they provide to develop the assessments and learning engagements.”

In summary, NGSS training sessions helped the respondents to develop assessments that tackle the performance expectation observable features by unpacking standards and setting assessments for those standards; and seeing the use of NGSS documents to develop meaningful GRASPS tasks and learning engagements.

Finally looking at Q17, the third question in this section is, How did your knowledge and competencies help you throughout this process?

All the respondents indicated that their knowledge and competencies of their subject area were helpful and useful to a large extent throughout the RCD-PBL process. The subject knowledge and competencies that each teacher possesses have led to higher confidence in the development and implementation process and allowed them to know the degree of flexibility and adjustment it requires while delivering such curriculum units. Respondent 1 shared, “...it builds you up and it builds your confidence...”.

Respondent 2 explained,

“Being competent and knowledgeable in your subject area will reinforce and increase your confidence level in the delivery, especially it allows you to know to what extent you can be flexible and take and perform some supplementary action when needed.”

Respondent 3 reported,

“It helped me a lot...My knowledge and competencies increased my confidence level in the delivery, it helped me to adjust, be flexible, and ensure that students are learning the needed. In addition, sharing experience and being knowledgeable in our subject area allowed us to design PBL tasks for which these units were built on.”

Respondent 4 stated,

“Content knowledge and my teaching experience helped me to better understand how to implement and deliver these PBL units. Sharing experience, discussions, and what works with all teachers across campuses we were able to filter the best practices that align the standards, teaching, and learning to the assessment. Being taught how to write a GRASPS task related to a problem or topic in the science field allowed us to use our knowledge and skills of the subject to set rubrics, design tasks, and most importantly know how to deliver, implement, and to what extent we need to support our students with the task.”

Respondent 5 said,

“...this helped me to understand what I should omit and what wasn’t important for the kids to incorporate. Put simply, it helped to draw better boundaries for what was being assessed.”

Respondent 6 put forward,

“Critical and creative thinking ...self-management...a growth mindset and a lot of resilience also helped because this can be a daunting process, but it has a positive and empowering impact on the students’ learning so it’s worth it.”

Based on teacher perceptions results on RCD-PBL professional development and subject knowledge and competencies, “Training and subject area knowledge and skills can help in the RCD-PBL process” was the theme generated for this section.

Section 5-Teachers’ Involvement in the RCD-PBL Curriculum Development

Two interview questions (Q18-Q19) were related to the teachers’ perceptions of their involvement in curriculum development. The first question (Q18) was, “To what extent do you think that your involvement, choice, and collaboration with other colleagues have helped set up such a curriculum? All six respondents indicated that their involvement, choice, and collaboration with other colleagues in the RCD-PBL curriculum development, helped to a large extent in setting up the curriculum. With regards to involvement, the perceptions of the respondents were that they had a voice, were active developers, and thereby provided personal input to the curriculum development, shared experiences and ideas, and got constructive feedback from RCD leaders and coaches and thus improved their understanding of how components are aligned. In terms of choice, the teachers were able to choose what was relevant to their students at their particular level, since they knew their students.

Teacher perceptions with regards to collaboration, were that it was beneficial to the teachers as it: resulted in building curriculum units with rigor; helped in vertical and horizontal alignment of PBL units; helped in the uptake of the pedagogy behind curriculum reforms; allowed sharing of ideas, knowledge, and experiences with colleagues by also taking into consideration the culture, context, interest, and needs of second language learners; enabled getting feedback from RCD leaders and coaches and thus improved their understanding of how components are aligned. Respondent 6 said that involvement, choice, and collaboration with other colleagues in the RCD-PBL curriculum development helped them extremely and shared,

“There is a synergy that comes from collaboration; you need thought partners to figure out the best path forward, keep you on track; check on alignment; bounce ideas around, and share best practices.”

Respondent 5 reflected,

“It made us share experiences, brainstorm ideas, and take into consideration students’ needs, choosing an interesting topic or project. Constructive feedback was always provided along the way by the RCD leaders and coaches. It made our voice stand out...It made us understand how the components are aligned, and why they need to be. How the standards should be delivered.”

Respondent 4 explained,

“Collaborative teamwork ...helped us to share experience and build rigor units and be part of the curriculum development team...we felt part of the community and the school...We understood the essence of how alignment was set and the importance of having such alignment.”

Respondent 3 put forward,

“Collaborative design in teams helped me in the uptake of the pedagogy behind curriculum reforms, such as the context-based approach in science education and communicative language teaching. And also, the development of subject-matter knowledge...”

Respondent 2 shared,

“... we are the only one that knows our students we were active developers whereby we share our knowledge and experiences and combined our skills into setting and developing these curriculum units taking into consideration the culture, the context, the interest, and the needs of our second language learners whereby English was their second language and the supporting materials and guidance was going to be different than for those who are native English speakers.”

Respondent 1 reported,

“I could see the flow of the units and how knowledge and skills were transferred and acquired throughout the scope of the units across and over the grade levels.”

As for the second question in this section (Q19), To what extent do you think that the collaboration and involvement of teachers in designing PBL units using the RCD process have reduced the time related to building lesson planners and assessments?

The majority of the respondents stated that collaboration and involvement of teachers towards designing PBL units using the RCD process reduced the time related to building lesson planners and assessments, and a minority stated that collaboration reduced time related to building lesson planners and assessments, provided if it was done properly the first time. Respondent 6 put forward a conditional response,

“I think if it’s done properly the first time in the short term, it reduces the amount of time spent astronomically in the long term...”

Respondent 5 said,

“Collaboration does help to reduce the time it takes to build lesson plans and assessments; however, when putting the RCD together as a complete package the same amount of time is still devoted to everything ... Throughout the year, not much has had to be amended to the unit planners or assessments because it has been prepared already.”

Respondent 4 explained,

“...RCD units ease our planning as all needed parts of the planner are in the units, but we can modify based on our students’ needs and levels, but the main parts and assessments are ready and in place to use.”

Respondent 3 reflected,

“It has for sure reduced the preparation time, especially, that end of last of the year required that significant time be spent planning, organizing, and collaborating.”

Respondent 2 said,

“It reduced the planning time as everything was preliminary planned out however, interaction, and the relationship between the teacher-students varied.”

Respondent 1 reflected,

“...ensuring the horizontal and vertical alignment across the science subject and setting in the PBL GRASPS task beforehand, has helped reduce the time related to building lesson planners and assessments.”

In summary, collaboration and teachers’ involvement can assist in the development and implementation of the RCD-PBL curricula. This was the fifth theme generalized from the interview.

Section 6- Students’ Achievement

The last section of the interview entailed two questions (Q20-Q21) related to students’ achievement. This section will help us better understand the reasons and provide recommendations from teachers’ perspectives towards the effectiveness of RCD-PBL on students' achievements and MAP scores results.

The first question (Q20) was, “Looking at Fall-Spring MAP data, how did the RCD-PBL curriculum impact the MAP scores results?” All six respondents affirmed that the RCD-PBL curriculum improved MAP scores although respondent 6 indicated the RCD-PBL curriculum on its own without proper implementation and teacher proficiency would not be enough to impact middle school science students’ MAP scores in Abu Dhabi, UAE. Respondent 1 stated,

“We plateaued for some time of the years.....we pinpointed that our major problems: curriculum (not-contextual, irrelevant, etc.), lack of students’ engagement in scientific subjects, traditional teaching strategies.... Centralizing PBL in the curriculum using the RCD led us to meet the growth expected. The growth was first measured internally with our standardized assessments.....while some students did big jumps others have shown a slow growth but that’s the impact of PBL by itself.”

Respondent 2 said,

“While improvement has been observed in both of the classes traditional and PBL however, the increment in RIT scores of the PBL classes was higher and more noticeable...”

Respondent 3 shared,

“While you can see improvement in both of the classes the PBL class has improved better than before as students have better reasoning skills that they are capable of applying and transferring their knowledge to unfamiliar real-world situations.”

Respondent 4 explained,

“Although my classes taught through the traditional teaching method showcase an improvement for some students in their MAP score, my RCD-PBL students showed a higher improvement in their RIT scores compared to the others. Although we may not have surpassed the average international norm level in some of our classes, however, this is set to be a good and effective initiative that leads the students to success and higher achievement especially since this is our first year of implementation.”

Respondent 5 reported,

“PBL curriculum is definitely having an impact on the MAP score results, however, I think it would just be an element of time to see an accumulation of that growth more and more. You can see that most of my students have improved or even meet the Growth target by increasing on an average of around 5-6 RIT scores compared to my traditional whereby students either stayed on the same level or improved slightly in their scores by an average increment of 1 to 3 RIT scores. I think the difference might be related to how the skills and knowledge were acquired. I can tell that my students taught using the RCD-PBL could recall and come back to some concepts as they still remember the project they worked on, the retention and the thinking skills were definitely enhanced in these classes compared to traditional.”

Respondent 6 reflected,

“With the caution that the process itself is not enough to see the impact – implementation is the key; students continue to close gaps and grow. The amount and speed of growth depend on the proficiency of the teacher. That said the RCD made sure that all teachers have a common understanding and that there is more consistency around expectations and outcomes.

The second interview question (Q21) was “In case there was no/weak development in students’ results, what are the reasons behind that? Any Recommendations?” Respondents stated various reasons for no/weak development in students’, ranging from pedagogical implementation of RCD-PBL (two respondents); examinations during Ramadan (one respondent); English as a second language/language barrier (one respondent); lack of parental involvement and support (two respondents); and to how skills and knowledge were acquired (one respondent). Most respondents recommended more parental involvement (four respondents) followed by more support from the administration (two respondents). A minority of the respondents advocated for Grade level curriculum unit reflection as a whole team (one respondent); CPD to support the implementation process (one respondent); liaising with the English Department and teaching English within science (one respondent); building efficacy of the teachers (one respondent); and administration, teachers and parents working together (one respondent). Respondent 1 put forward that some students struggled because the language of instruction, English, is their second language,

“So, most of the students who did not grow or struggle to grow are the students that were struggling with the language itself. Although any teacher is a language teacher, more collaboration with the English department might be set to unify the strategies that we use to introduce the language to our students.”

Respondent 1 further added that,

“... it is important that we involve parents in every step of the way, having parents' buy-in and seeing the impact on their student's success will make the difference needed. However, we need to make sure to inform the parents of the importance of students

executing the GRASPS (assessments) found in each unit, by themselves, as these performance tasks allow the students to apply and transfer their knowledge and use their skills to address or solve a problem.”

Respondent 2 suggested,

“... to keep monitoring the impact on MAP for the upcoming years...MAP testing for the spring has taken place during Ramadan when students are fasting and with this, we have seen such an impact... Increasing parents’ involvement...working hand in hand (admin, teachers, and parents) will lead to definite success.

Respondent 3 proposed,

“ ... additional parental involvement with informative sessions would have helped students to easily adapt to the new system. Also, having parents support and follow up with their children makes the child more engaged and willing to give and do his/her best to make their parents proud.”

Respondent 4 advocated,

“More parental engagement and involvement, stress on grade level curriculum unit reflection as a whole team, additional CPD to support the implementation process could be the recommendation needed for better improvements.”

Respondent 5 acknowledged the support from the administration, but urged,“...more support by initiating this process in other subjects [sic] will help. In addition, parents’ involvement ...involving them continuously and showing them the importance of such approach is integral.”

Respondent 6 recommended building the efficacy of the teachers.

Finally, based on teachers’ perceptions towards students’ achievement, the final and last theme generated was “RCD-PBL curriculum can contribute to the improvement in MAP scores”.

4.3.2 Summary of Qualitative Results

Six interview transcripts were analyzed and uploaded in QDA Miner Lite v2.0.9 free edition. Qualitative analysis results from the thematic analysis show that the majority of the respondents/interviewees believed that:

- RCD model framework can help in understanding the standards, instructions, and assessments, ensuring vertical and horizontal articulation and development of high-quality curricula;
- RCD-PBL units are student-centered, more engaging, build skills, allow knowledge transfer, and are an effective approach to teaching and learning science;
- RCD-PBL gave continuity to the units and provided the teacher with a deeper understanding of PBL.
- Despite certain challenges, RCD-PBL is more relevant than the textbook curricula.
- PBL tasks were relevant, contextual, and authentic which made learning purposeful and increased students' engagement.
- Training and subject area knowledge and skills can help in the RCD-PBL process;
- RCD-PBL training helped teachers understand and visualize how RCD and PBL elements overlap with each other, ensuring a better understanding of PBL; understand the importance of transferring the concepts to real-life applications;
- RCD-PBL trained teachers on how to approach, implement, support, and guide the students through the unit project (GRASPS).
- RCD-PBL training sessions have empowered teachers and prepared them to be curriculum developers.
- RCD-PBL trained and involved teachers in writing and developing relevant and meaningful GRASPS tasks that meet the standards while highlighting the importance of scaffolding and differentiation in meeting students' needs.
- NGSS training sessions helped teachers understand what students should know and be able to do after dissecting and unpacking the standards;
- NGSS training sessions helped teachers develop assessments that address the performance expectations observable features by unpacking standards and seeing the use of NGSS documents to develop meaningful GRASPS tasks and learning engagements;

- Collaboration and involvement can assist in the development and implementation of RCD-PBL curricula;
- Teacher perceptions towards collaboration resulted in building curriculum units with rigor; helped in vertical and horizontal alignment of PBL units; improved their understanding of how components are aligned, allowed sharing of ideas, knowledge, and experiences with colleagues and helped in the uptake of the pedagogy behind curriculum reforms;
- RCD-PBL curriculum can contribute to improvement in MAP scores.
- Parental involvement and support will help their children adjust much faster to the new type of approach and assessment and perform better.

4.4 Triangulation of Quantitative and Qualitative Data

Quantitative and qualitative results are compared for some of the items in the questionnaire and interview transcript questions. The results for the items shown in Table 70 are almost similar.

Table 70: Quantitative and Qualitative Results

Items	Quantitative (%)	Qualitative (%)
RCD is aligned with PBL components	100	83
Confident about the application of RCD	96	83
Application of knowledge acquired to the real-world contexts	92	100
RCD planning process is student-centered	84	67
PBL and assessment engaged students in problems or questions to make learning more meaningful	96	100

Qualitative and quantitative results agree in the sense that RCD for PBL can improve MAP scores. The respondents to the questionnaire and the interview questions have positive perceptions of the RCD-PBL although some were initially reluctant to let go of their students and adopt the student-centered approach which is more engaging and more relevant to solving real-world problems with the students learning skills such as collaboration, critical thinking, and communication. Quantitative and qualitative results show that the perception of the teachers evolved, and the respondents indicated that they now have more confidence in PBL.

Results from the quantitative and qualitative data analysis of this study agree with the findings by Holm (2011) who showcased how PBL is the key to shifting education towards student-centered methods and curriculum that is based on hands-on inquiry and active learning whereby teachers' involvement and guidance are imperative. His finding revealed that PBL methods resulted in a greater impact on academic achievement and improved students' engagement compared to the traditional method. Moreover, the students highlighted that not only has this approach increased their engagement and interest in the subject under study but also increased their understanding and subject content knowledge.

CHAPTER V: DISCUSSION, CONCLUSION, LIMITATIONS, AND RECOMMENDATIONS

5.1 Overview

The current research was conducted using an explanatory sequential mixed method design to address the three-fold purposes of the study. Triangulation evidence was implemented to provide the required information for this research study. This evidence was gathered by using four various instruments which include: the Science Standardized Knowledge Test (SSKT), the Measure of Academic Progress (MAP) test, the middle school science teachers' questionnaire, and the middle school science teachers' interviews.

The SSKT and MAP test data analysis results aimed to explain students' progress results in science standardized tests and MAP exams in the light of Rigorous Curriculum Design (RCD) for Project-Based Learning (PBL) implementation in an American private school in Abu Dhabi, UAE. The teachers' questionnaires and interviews aimed to investigate teachers' perceptions regarding the RCD-PBL development, implementation, and effectiveness in science.

The data was gathered by using a mixed-method approach. The research results from the four utilized instruments are integrated and discussed in light of the theoretical framework of the study. The results are discussed according to the sequence of the research questions. Furthermore, the present chapter includes the findings of the study in relation to the research questions and their discussions; along with recommendations, implications, limitations, and concluding remarks.

5.2 Discussion

This study aimed to investigate the effectiveness and teacher perceptions of Rigorous Curriculum Design for PBL implementation on middle school science students' achievement and Measure of Academic Progress scores in Abu Dhabi, UAE. The three main questions that drive this study aim to shed light on the importance of having a suitable and sustainable curriculum model that is driven by project-based learning principles and practices to enhance students' results in Standardized Science Knowledge Tests and MAP scores are:

RQ1. To what extent does rigorous curriculum design for project-based learning implementation affect middle school students' achievement in science standardized knowledge tests, in Abu Dhabi, UAE?

RQ2. To what extent does rigorous curriculum design for project-based learning implementation affect middle school science students' MAP scores in Abu Dhabi, UAE?

RQ3. What are middle school teachers' perceptions towards rigorous curriculum design for project-based learning development and implementation in science?

To address the aim and research questions, the study involved both quantitative and qualitative analysis of data. The data comprised of:

- Grades 6, 7, and 8 pre-test and post-test SSKT scores of middle school students from private schools in Abu Dhabi, UAE;
- MAP scores for fall 2021 and spring 2022, for grades 6, 7, and 8 middle school students from private schools in Abu Dhabi, UAE;
- Questionnaire data from 25 respondents and;
- 6 interview transcripts.

The following sections present the discussion that is related to each research question.

5.2.1 Effect of Rigorous Curriculum Design for Project-Based Learning Implementation on Middle School Science Students' Achievement in Abu Dhabi, UAE.

The RCD for PBL implementation had a positive and substantial ($p < .05$) significant impact on improving middle school students' achievement by increasing their SSKT scores as indicated by the results of the statistical analysis performed along with Cohen's d-effect size values. The findings of the statistical analysis revealed that the mean difference of the middle school experimental group (SSKT Pre-Posttest) was greater than the mean difference in the matching control group. This indicates that PBL is more effective in raising SSKT scores compared to traditional teaching following textbook-based curriculum (non-PBL) in science subjects as advocated by several research studies (Yalçın, Turgut & Büyükkasap 2009; Ergul & Kargin 2014; Khaliq, Alam & Mushtaq 2015). This is comparable to 88% of teachers' responses who affirmed from the questionnaires (68% agree and 20% strongly agree) that after they taught their first RCD-PBL unit, students demonstrated improved achievement in pre-versus post-assessment of the unit. These results agree with the findings of other authors. Khaliq, Alam, and Mushtaq (2015) used a pre-posttest design to evaluate the effectiveness of PBL on grade 8 academic achievement in an environmental topic and the results showed an increase in science academic achievement for the experimental group. Ergul and Kargin (2014) conducted a study

in which they analyzed through a quasi-experimental method, the effect of PBL on grade 6 students' success in the electricity in life unit in two elementary schools in Turkey, and their study revealed that PBL increased students' achievement when comparing pre-test and post-test results between experimental and control groups. Rubrica (2018) studied the effect of PBL on the academic achievement of two grade 6 sections, from Sta Quiteria Elementary School in Caloocan City, in science. Pre-posttest was administered to both control and experimental groups and results indicated a statistically significant difference in terms of students' achievement. However, the findings of this study contradict with other studies that investigated the effect of PBL on science achievement and observed no impact on students' outcomes (Araz & Sungur 2007; Yalçın, Turgut & Büyükkasap 2009; Ayan 2012; Kizkapan & Bektas 2017)). Ayan (2012) found no significant difference between the achievement test post-test scores of the experiment and control groups in the unit of light at a fifth-grade level. The same was observed in Kizkapan and Bektas's (2017) quasi-experimental research study whereby they investigated the effect of PBL on middle school grade 7 students' achievement in a chemistry unit pre-post-test. Convenience sampling was used to select the participants and an independent samples t-test was performed to analyse the data. However, no significant difference between the experimental and control groups' scores was observed. According to Kizkapan and Bektas (2017), this may have been caused by several factors, such as the minimum instructional time allocated (only four weeks) while the minimum time to deliver a PBL unit is six weeks (Ainsworth & Donovan 2019), teachers' role, the unfamiliarity of students and teachers towards this approach, topics delivered, and communication between group members.

In addition, one-way ANOVA results corroborated the results from the independent samples t-test in that, the improvement in the SSKT scores of the PBL group was substantially different ($p < .05$) and higher than the improvement in the SSKT scores for the non-PBL group, meaning that RCD for PBL affects middle school students' achievement in SSKT, in Abu Dhabi, UAE. The mean improvement in SSKT scores for grade 6 was the lowest at 3.83, followed by grade 7 at 4.39 and grade 8 at 5.59. This shows that RCD-PBL likely has a greater influence on higher middle school science end than in its lower grades. This could be a contribution as most of the research studies performed on the effectiveness of PBL were done on one single grade level (Bas 2011; Karaçalli & Korur 2014; Redmond 2014; Kizkapan & Bektas 2017; Sahli 2017; Krajcik & Czerniak 2018; Chen & Yong-Cih 2019) rather than

comparing its impact among a specific cycle and subject. Furthermore, it has been indicated that there is a statistically significant interaction between the grade level and group*gender on the SSKT mean improvement scores as indicated by a two-way ANOVA analysis. Specifically, when experimental female outperformed all groups in grade 6 while the experimental male group outperformed the other groups in grades 7 and 8. Moreover, the simple main effect has confirmed that the RCD-PBL has a significant impact in grades 6 and 8 and grades 7 and 8 ($p < .05$) as confirmed by LSD and Tukey honestly significant difference (HSD) multiple comparisons post hoc tests, more specifically for experimental male. These findings suggest that gender may influence the SSKT scores.

Looking through previous studies, it has been reported that males students are more interested in science fields than females, specifically in STEM fields as most scientists are men and due to the role, interest, and confidence level of females (Makarova, Aeschlimann & Herzog 2019; Jia et al. 2020). Introducing PBL in the curriculum specifically in science will increase all students' interest in STEM specifically females (SEHD communications 2021) since the RCD allows students to reach a higher level of quality in students effort and outcome (Ainsworth 2011; Ainsworth & Donovan 2019) by achieving the designated grade level requirement and standards with a subject as reported in the study theoretical framework (Ainsworth 2011; NGSS Lead States 2013; Holthuis et al. 2018; Ainsworth & Donovan 2019). In addition, taking part in a meaningful and engaging learning experience and projects that are aligned to clear learning outcomes (Ainsworth & Donovan 2019) allow students to take on the role of scientists and explore multiple concepts and discuss ideas and solution related to a real-world problem or challenge (Holthuis et al. 2018; Buck Institute for Education 2019a). Thus, transfer and deepen their knowledge and skills and increase their confidence levels and interest in this subject.

Furthermore, the positive impact of RDC-PBL on enhancing middle school students' achievement in science standardized knowledge tests, in Abu Dhabi, UAE, aligns with similar findings from previous studies mostly carried out in Western and East Asian countries regardless of the group size or educational stage (Araz & Sungur 2007; Yalçın, Turgut & Büyükkasap 2009; Ayan 2012; Kizkapan & Bektas 2017; Kwietniewski 2017; Chen & Yong-Cih 2019; Krajcik et al. 2021; Liu, Fan & Wang 2021; Saavedra, Liu & Haderlein 2021). Thus, this research study will contribute to the literature in terms of the effectiveness of such an

approach once centralized in a curriculum developed by teachers on students' academic achievements in the Middle East region, specifically in Abu Dhabi.

Finally, the outcomes of the research question demonstrate that when PBL is centralized in the curriculum an increase in students' achievements on standardized science knowledge tests is observed specifically in middle school science classes in the Middle East region. This addresses the gap highlighted in literature by (Kwietniewski 2017; Aldabbus 2018; Rubrica 2018; Yokom 2020) in terms of the impact of PBL on students' achievement when centralized in the curriculum. As male and female students outperformed each other's in different grade levels, studying the impact of PBL on gender achievement along with factors that impact their achievements and readiness to STEM would be recommended.

5.2.2 Effect of Rigorous Curriculum Design for Project-Based Learning Implementation on Middle School Science Students' MAP scores in Abu Dhabi, UAE.

Rigorous curriculum design for project-based learning implementation affects middle school science students (grades 6, 7, and 8) MAP growth scores for Fall 2021-Spring 2022 in Abu Dhabi, UAE, at the 5 % level of significance. Results from inferential statistics showed that there is a statistically significant difference between the RCD-PBL groups versus textbook-based curriculum (non-PBL) groups for middle school classes (grades 6, 7, and 8) in terms of mean MAP growth scores in science. The grade levels who implemented the RCD-PBL demonstrated greater academic growth than their counterparts who received textbook-based instruction and thus, confirmed the positive effect of implementing and centralizing PBL in the curriculum using the RCD model for a full academic year. The results and suggestions of Holm (2011) and Kwietniewski (2017) are in line with this study's findings. While both have showcased that PBL implementation results in a greater impact on academic achievement, Kwietniewski (2017) concluded that these results would be further enhanced and increased if the curriculum is re-designed in a way to accommodate the implementation of PBL as an instructional approach and assessment type. Furthermore, the MAP scores results of this study matched with Sahli's (2017) and Redmond's (2014) findings whereby they revealed respectively that PBL achieved higher MAP growth scores average in reading (grades 4,5,6, and 8), in Math (grades 4, 5, and 6) and an increase in grade 4 academic achievement in science MAP testing through active learning, collaboration, and meaningful project. This was as well perceived and communicated by all the six interviewees that participated in this study

Furthermore, the improvement in the science students' MAP growth scores has been observed across all grade levels (grades 6, 7, and 8) (63%) in the two campuses in the Emirate of Abu Dhabi, UAE, and for both genders. This is aligned with Eze, Onwusuru, and Ginigeme's (2021) study who concluded that the PBL method improved both male and female college students from Anambra state academic achievement based on the results of a Basic Electricity Achievement Test made of 40 multiple choice questions. While all students taught using the RCD-PBL either improved or met the projected growth, (14%) of their peers in non-PBL (textbook-based curriculum) classes neither improved nor declined in their MAP scores. Moreover, RCD-PBL implementation has increased five times the percentage of students that met the projected growth (58%) in comparison to their peers taught using the textbook curriculum (11%) from Fall 2021-Spring 2022. These results confirm Vygotsky's theory (1978), whereby social collaboration is a critical component of the learning process. It can foster a deeper understanding of students' cognitive development, which occurs first on a social level and then on an internal level. Furthermore, Vygotsky stated that the improvement in student learning will be produced in the zone of the student's ZPD with the assistance of teachers inside the classroom (Vygotsky, 1962). If teachers can assist students in learning and take a role of a facilitator in PBL curricula, students will learn more easily within the ZPD zone, proving Vygotsky's point about the importance of assistance. When learners complete the initial task, their ZPD zone expands, and they can accomplish more. This includes the social constructivist strategy, for which students are given a choice and decide on tasks or products they can do independently and then, with the help of their teacher and/or peers, learn new ideas and concepts based on their previous experience.

Moreover, it has been shown that male students outperformed female students by meeting the expected MAP projected growth scores in grades 6 and 7, in comparison to grade 8 whereby female students outperformed the male students. This is in agreement with some previous research studies that have shown that male students outperform female students in external standardized assessment rather than internal as female are usually more worried and stressed in the exams (Akinsola & Fisayo 2014; Lupinski & Jenkins 2014; Saygin 2018; Jia et al. 2020). For instance, this was confirmed by Lupinski and Jenkins (2014) who concluded based on a study done on grades 3, 5, and 8 students' scores in Georgia Criterion-Referenced Competency standardized Test in Reading, English/Language Arts, Math, Science, and Social

studies, that while female outperformed male in English and Social studies, male outperformed them in Math and Science, especially in grades 5 and 8. Also, Saygin's (2018) research study conducted in Turkey on high school students' college admission relied on high scores internal scores and standardized external test scores whereby the study showed that while females performed better on internal assessment than male students, the male outperformed them in standardized testing as females tend to be more anxious and worried when they sit for standardized test compared to male. However, seeing that female students outperforming the male students in grade 8 in MAP might be due to the fact that PBL might have increased their confidence and engagement levels in science which helped lower their anxiety levels. In addition to the fact that at this stage and in this context, female students are more mature, undertake more responsibility, and understand more the impact of such exams on their career pathways and life opportunities. This is observed in PISA results (OECD 2019b) whereby male outperforms female in standardized test and external exams except in Middle Eastern countries in general and in UAE in particular whereby female outperforms male.

Finally, such an increase in students' average MAP growth scores indicate that this curriculum design has allowed students to gain and retain knowledge and improve their skills through proper implementation and alignment of NGSS with teaching and learning, and assessments. This is due to teachers' involvement in planning, developing, and implementing such curricula as advocated by several research studies (Ainsworth 2010; Holm 2011; Hattie 2012; Redmond 2014; Alsubaie 2016; Capraro et al. 2016; Kizkapan & Bektas 2017; Konokman et al. 2017; Ainsworth & Donovan 2019; Bediako 2019; Chen & Yong-Cih 2019). As well as the importance of students' role and active involvement in the learning process as highlighted in the theoretical framework of this study (Dewey 1938; Vygotsky 1978; Thomas 2000; Holm 2011; Kingston 2018).

Although the outcome of this study confirmed that the RCD-PBL curriculum could largely impact middle school students' MAP scores, this effect could be enhanced, especially since this is the first year of implementation whereby teachers and students are getting used to such curriculum (Kizkapan & Bektas 2017). Also, some other factors could contribute to students' achievement (environment, parents' involvement, and support, resources, teacher students' relationship, etc..) as discussed in the conceptual framework and the literature sections of this study. Furthermore, the amount of time it requires to effectively implement and introduce

the PBL tasks and build the higher order thinking skills and engage them in projects that will deeper their knowledge, increase their motivation, and upskill them (Aldabbus 2018; Rubrica 2018; Yokom 2020).

5.2.3 Middle School Teachers' Perceptions Towards Rigorous Curriculum Design for Project-Based Learning Development and Implementation in Science.

To examine and explore teachers' perceptions towards the RCD-PBL development and implementation, questionnaires and interview sessions were conducted. While the questionnaire grasped (N=25) teachers' perceptions using Likert scale type of questions, interview sessions were carried out with six middle school science teachers that were involved in the development and implementation of these curriculum units to gain a better and deeper understanding of their responses. Six major themes that summarize and highlight the respondents' perceptions were generated from the analysis of the interviewee's responses, whereby the discussion of results will happen within each theme generated.

Theme 1: The RCD model framework can help in understanding the standards, instructions, and assessments, ensuring vertical and horizontal articulation and the development of high-quality curricula in science.

All respondents have indicated how RCD have involved, empowered, and prepared them to be curriculum developers. In addition, they have highlighted how the steps offered by such a model have helped them in understanding the alignment between standards, instructions, and assessments, which lead to vertical and horizontal articulation and the development of high-quality curricula. Although the efficacy of curriculum components alignment is not widely studied in the literature (Squires 2012), Squires (2009) discussed the powerful alignment between these components and their effect on students' achievement which this study focused on and investigated. Moreover, the respondents believed that the RCD framework resulted in the development of a high-quality curriculum since it provides a broad overview with the scaffolding of knowledge as it is based on a backward design model, standards, and proficiency on external examinations (Wiggins & Mc Tighe 1998; Wiggins & McTighe 2005; Bowen 2017). This is in line with the findings of some authors (Ainsworth 2010; Sahli 2017; Ainsworth & Donovan 2019; Pondiscio 2020) who revealed that designing a high-quality student-centered PBL curriculum based on RCD provides a coherent, cumulative, and well-sequenced enriched

curriculum that deepens and broadens with each grade level. In addition, Capraro and Slough (2013) stated that PBL adopted within the RCD combines theory to experience, and endorses students' knowledge and skills they face through solving ill-defined problems by utilizing their cooperative abilities. Therefore, this instructional strategy will identify the multiple potential levels of students which is related to their particular learning abilities and learning styles (Ainsworth 2010; Ainsworth & Donovan 2019) and scaffolds students' needs by tailoring them to their current level of understanding (Condliffe et al. 2017). While Krajcik and Shin (2014) and Darling-Hammond et al. (2008) consider scaffolding to be a main component of PBL they believed that it should be faded over time as students learn to apply on their own the new knowledge and skills (Puntambekar & Hubscher 2010). Finally, interviewees and (87%) of the questionnaire respondents have mentioned that their involvement and collaboration with experts and curriculum developers which RCD brought together as a factor, leads to building a high-quality coherent curriculum. While such empowerment and involvement in the developmental process have been elucidated by lots of researchers (Carswell 1977; Ben-Peretz 1980; Klein 1985; Handler 2010; Luciano 2014; Capraro et al. 2016; Konokman et al. 2017) the results of this study will be one of the few (Habók & Nagy 2016; Konokman et al. 2017) that evaluated and grasped their perception about the efficacy of their involvement and role as curriculum developer and implementer.

Theme 2: RCD-PBL units are student-centered, more engaging, build skills, allow knowledge transfer, and are an effective approach to teaching and learning science.

Based on the respondents' replies, findings showed that RCD-PBL units are student-centered as compared to the traditional curriculum which is teacher-centered. This methodology allowed more student engagement and knowledge transfer which results in building of skills. This theme is in line with literature whereby several research studies investigated the effectiveness of PBL (Thomas 2000; Holm 2011; Nassir 2014; Redmond 2014; Ergul & Kargin 2014; Karaçalli & Korur 2014; Ayaz & Söylemez 2015; Khaliq, Alam & Mushtaq 2015; Aidoo et al. 2016; Condliffe et al. 2016; Sahli 2017; Kwietniewski 2017; Mahasneh & Alwan 2018; Rubrica 2018; Chen & Yong-Cih 2019; Saavedra, Liu & Haderlein 2021; Krajcik et al. 2021) in deepening students transfer skills (problem-solving, analytical skills, critical thinking, communication, teamwork, and collaboration) in different subjects as well as increasing

academic achievement, engagement, application and retention of knowledge. All interviewees affirmed that the contextual projects have increased their students' interest and curiosity in science, which is also supported by Khaliq, Alam, and Mushtaq (2015), who highlighted that PBL was found to be an effective approach to teaching science as it stimulates students' inquisitiveness to explore and recommended this approach to be used in all science subjects. This was observed for example in the grade 8 GRASPS task whereby students taking on the role of mechanical engineering working for the UAE red crescent, felt involved and responsible in finding a solution to dropping emergency supply pods to areas that have been affected by natural disasters such as earthquakes and floods. Furthermore, the results were aligned with Helmane and Briska (2017) who suggested that, as learning revolves around performance-based assessments such as projects that combine two or more disciplines, the integration will be one aspect of this curriculum. This integration allowed students to deepen and broaden their knowledge and skills related to group work, communication, design, construction, research, and investigation. Looking over the performance task specifications and standards addressed in of grade 8 supply pod GRASPS task, students had to conduct research, define, optimize, and develop possible solutions to an engineering problem "Request for proposal of the development of a supply pod by the UAE red crescent foundation to hold emergency supplies as they are delivered to people in need by a helicopter" based on forces and motions concepts in groups and through effective communications and discussions. These performance expectations are integrated with the Common Core State Standards for ELA and Mathematics in terms of allowing students to use effective academic language, words, and phrases sufficient for reading, writing and speaking next to citing and drawing effective text evidence to support their analysis to recognizing and representing proportional relationship between quantities for example "Forces, mass, and velocity". Findings from the interview transcripts showed that some respondents believed that the final product enabled students to demonstrate their knowledge and understanding of scientific concepts unpacked from the standards and taught within each unit of inquiry through communication (orally, writing, or visually) and knowledge transfer to unfamiliar situations. This was highlighted by Condliffe et al. (2017) who showed the positive impact of such performance tasks aligned to the NGSS and delivered through the PBL curriculum. The transfer of knowledge to unfamiliar situations was also advocated by Stock (2018) and the international baccalaureate framework (IBO, 2013) who have highlighted the

importance of becoming lifelong learners, acquiring real-life skills (TNS Beaconhouse Defense 2018), through active participation in their learning process through authentic, meaningful, and contextual projects. Such involvement leads to higher students' performance levels and high-order thinking skills as elucidated by Marzano (2007). Moreover, these results were also specified by Dewey's experiential learning theory (Dewey 1916) whereby he highlighted the importance of revolving learning around students and involving them in purposeful practical experiences, activities, and projects that are connected to their environment. Conducting research, investigations, and tests by students in order to develop a supply pod design that minimizes the cargo damage and maximize the shell condition while keeping the costs low has allowed students to look at a variety of outer shell material types such as water-light shelter, building materials, non-reusable materials, etc.. and their properties and evaluate the effect of each inner padding for example air bags, metal foam, feather, paper pads, and more on the impact of the dropping of supply pods with top or and bottom adds-on such as parachute, foam blocks or any other equipment that might reduce the impact force. Students looked into and evaluated the concepts of collision and impact forces as well as mass, velocity and impact forces closely since keeping the content of the supply pod safe requires engineers to keep the impact force as small as possible. Through asking questions, teacher guidance, and research students were capable of identifying the three factors that affect the size of the force when pod hits the ground (collision time, mass of the pod and the velocity of the pod). Furthermore, looking back at the questionnaire results, most of the teachers' highlighted that the PBL units developed using the RCD model:

1. foster students' own disposition to recognize when and how to use the key competencies
2. Take into consideration Emirati students' society and culture
3. Develop their thinking skills
4. Encourage collaboration with other members
5. Allow students to use the knowledge acquired in meaningful real-world contexts

This confirms the alignment between the RCD attributes and Buck Institute for Education Gold standard PBL model highlighted by other authors (Eckersall 2017; Sahli 2017; Ainsworth & Donovan 2019; Buck Institute for Education 2019a). Moreover, the participating teachers indicated that students demonstrated their competencies in using the essential skills set for each

unit of inquiry project by presenting to an audience and through written reports. This was advocated by several research studies authors (Polman et al. 2014; Lenz et al. 2015; The National Academics of Sciences 2019) who have stated that presenting to an audience (experts) allowed students to embrace their skills and expand and transfer the application of knowledge beyond their classroom walls. Furthermore, the respondents mentioned that the RCD-PBL units have given students more opportunities to interact with their colleagues through collaboration and peer tutoring. Such opportunities, specifically peer-tutoring, have shown to increase students' engagement in the learning process, enhance their interest, and improve their achievement and academic skills (Rizve 2012; Ullah, Tabassum & Kaleem 2018; Moliner & Alegre 2020). Thus, allowing students to acquire emotional and social skills such as teamwork, communication, and conflict resolution (Darling-Hammond, Flook, Cook-Harvey, Channa Barron, et al. 2019). This was also elucidated by Vygotsky (1978) who highlighted in his social constructivist learning theory the importance of peer-tutoring in acquiring knowledge from a student as a mentor (tutor) and scaffolding the learning through teacher guidance that will allow students to move from the zone of proximal development to reach the next stage of understanding and take ownership in their learning. Finally, working in groups allowed students to share different experiences and perspectives and collaborate as a team to address problems, ask questions, investigate their answers, reflect, and revise and execute the project on which PBL inherently relies on (Buck Institute for Education 2017, 2019a).

Theme 3: Despite certain challenges, RCD-PBL is more relevant than the textbook curricula.

Writing and designing RCD-PBL units were rated by teachers as flexible, uncomplicated, practical, reasonable workload, easy to implement, and aligned with PBL components. These findings concur with Kwietniewski (2017), who performed a literature review on PBL mainly in the United States whereby he deduced that PBL is a very effective instruction approach that is flexible and uncomplicated in terms that teachers can adapt projects to meet the needs of their students. According to the responses received through the interview and questionnaire, the receptivity of most respondents in terms of relevancy, likeability, faith in PBL, and confidence levels towards RCD-PBL development and implementation has increased. Although, at the beginning of the implementation, few respondents were reluctant to move

towards a student-centered approach and often reverted to the lecturing method. This could be related to their level of readiness and confidence toward delivering PBL especially since such challenges were one of the major obstacles that affected PBL implementation in literature whereby teachers needed to be more upskilled and confident to be ready to implement such curriculum without being afraid of losing control over the students as the classes were becoming more active than before (Habók & Nagy 2016; Aldabbus 2018; Handrianto & Rahman 2018). However, according to most of the respondents, these challenges were overcome throughout the implementation and due to the professional development sessions that helped them to understand the best way and approach they need to adopt to implement and deliver PBL. This was supported by the questionnaire results related to RCD-PBL receptivity, whereby most of the teachers strongly agree or agree with RCD alignment with PBL components (100%), its ease of implementation (92%), the straightforward processes and procedure for creating such curriculum units, and confidence in the RCD-PBL implementation (96%). Abandoning their standard teaching methods, along with developing and understanding the new perspective on teaching and learning was mentioned by Mentzer, Czerniak, and Brooks, (2017). Whereby effectively implementing PBL impacted students' outcomes. This was highlighted in the teachers' responses and advocated by Tamim and Grant (2013) and Erdogan et al. (2016).

Additionally, teachers valued that PBL increased students' engagement and focused on regaining that sense of ownership and creativity that students inherently had, along with developing their skills, and providing the support and guidance needed throughout this implementation. This was observed by the diversity of the products delivered by students for example some presented their proposal in forms of a model for which they have tested, others used a simulation to showcase their design and presented their outcome using a PowerPoint presentation. However, they have highlighted that changing students' mindsets and setting thinking routines required effective teaching and learning time. In addition, most of the respondents have highlighted that although the implementation of such curriculum units required less planning time than before as collaboration and units' developments were done priorly, embedding deeper understanding and allowing students to be able to retain and transfer knowledge and use their skills in unfamiliar situations requires time. The saving in time increased as they were progressing from one unit to another since students became more familiar with and more used to the teaching approach and assessment type used in science. This was

explained by Aldabbus (2018) who highlighted that in the initial implementation stages, PBL may take longer than any other teaching method until both teacher and students get familiar with the principle of practicing this method. This was in accordance with the respondents' feedback to the questionnaire whereby 88 % of the respondents either strongly agreed or agreed with the fact of RCD-PBL has reduced the planning and preparation workload during implementation with more focus on differentiation and feedback.

Furthermore, because students may not be used to such methodology and may not have the skills and resilience to cope, next to their attitude, and perceptions towards being self-regulated learners during the implementation of PBL this might influence their achievement and affect the implementation process as reported by some respondents. While the academic success of students is greatly influenced by their attitude toward learning, as confirmed by several research studies (Han et al. 2015; Sölpük 2017; Lito D. Mallillin et al. 2021), it has been shown that having a negative attitude might make students less motivated, less interested in studying, and more academically challenged. Therefore, teachers have highlighted the importance of parental involvement, support, and relationship with their children as means to help them adjust faster to the new changes. Specifically, since parental involvement and collaboration have been pinpointed in literature (Aldabbus 2018; Dignath & Büttner 2018) as a factor that influences their children's attitude, behavior, and impacts the success of any educational process (B. McNeal Jr 2014; Engin 2020).

Nevertheless, all respondents stated that the RCD-PBL is more relevant than the teacher-centered textbook-based curriculum. According to the teachers, RCD-PBL impacts students' achievement by engaging them in meaningful, contextual, and authentic tasks that meet their needs and increase their interest in science rather than one size fit all task. This was strongly agreed and agreed by most of the participating teachers in the questionnaire (96%) whereby such an approach has outperformed other pedagogical approaches specifically traditional instructions as highlighted in the literature (The National Academics of Sciences 2019; Krajcik et al. 2021; Saavedra, Liu & Haderlein 2021). In addition, the impact of using a student-centered collaborative strategy in terms of gaining deeper thinking skills, obtaining new meaningful experiences, and constructing cognitive internalization of knowledge compared to the traditional approach has been highlighted by Zulfiqar and Alvi (2019). Furthermore, the literature has highlighted the positive impact and the effect of RCD-PBL in math and reading

(Sahli 2017) and science (Redmond 2014) MAP scores, as well as in advanced placement classrooms (Saavedra, Liu & Haderlein 2021) and in elementary science classrooms (Krajcik et al. 2021). Literature has shown that for nearly 6000 students in 144 different schools across the country, those taking AP classes outperformed their conventional class counterparts by a margin of 8%. Finally, the coherence and alignment between the standards (NGSS), instructions, and assessments (GRASPS) within the RCD lead to a higher understanding of scientific concepts and skills according to each student's level and needs (Vygotsky 1978).

Although teachers' have faced some challenges as a result of a change in curriculum approach, teaching strategy, and assessment type, most of these challenges were overcome by time with the help and support of their coaches, and coordinators and through continuous professional development sessions which were proven to be an effective way of addressing the PBL implementation challenges as elucidated by several research studies (Handler 2010; Luciano 2014; Han et al. 2015; Alsubaie 2016; Capraro et al. 2016; Viro et al. 2020; Haatainen & Aksela 2021). However, based on teachers' perceptions, the challenges faced when PBL was centralized into the curriculum were far less than the ones mentioned by literature when PBL was implemented as a peripheral approach to the curriculum. Finally, while teacher willingness, readiness, and engagement impact the implementation of PBL, their involvement in developing and implementing the PBL curriculum along with upskilling them through continuous professional development have reduced the impact of such factors.

Theme 4: Training and subject area knowledge and skills can help in the RCD-PBL process.

Collaborative planning and development of the RCD-PBL units with relevant learning activities along with professional development sessions and writing and developing standards-based students and PBL assessments that address the standards were the key component strength enumerated by teachers for designing and delivering PBL units. While training sessions were pinpointed as a main important factor that influences the development and implementation of these PBL units next to proper coaching and feedback, respondents have highlighted the importance of teacher-initiated PBL curricula whereby their involvement in developing and designing such curricula with the proper resources and continuous professional development

leads to preparing lifelong learners as students are exposed to authentic, meaningful real-world projects (Thomas 2000; Parker et al. 2013).

Moreover, the professional development conducted on RCD, PBL, and NGSS not only upskilled the teachers on how to use their knowledge and competencies in developing such curricula but allowed them to change their perceptions and confidence levels through continuous practical training sessions. This was in agreement with the questionnaire responses whereby 92% of the participating teachers strongly agreed on the efficiency and the importance of professional development in equipping them with the necessary knowledge and skills. Several research studies in the literature supported and highlighted the need for professional development and its importance in terms of upskilling teachers which leads to the success of curriculum development and implementation (Handler, 2010; Luciano, 2014; Han *et al.*, 2015; Alsubaie, 2016; Capraro *et al.*, 2016; Viro *et al.*, 2020; Haatainen and Aksela, 2021) and impact students achievement (Capraro et al. 2016). These results are supported by Capraro et al., (2016) who strongly suggested that teachers should be exposed to professional development to align their beliefs with the PBL approach which give them the pedagogical skills needed to design and implement such changes in their practices. This reflects the significant need to provide teachers with continuous professional development programs for which UAE is concentrating as an important part of their educational reform as per their National Agenda 2071 (*UAE Centennial 2071* 2022).

Finally, the subject area knowledge greatly assisted the respondents in the RCD-PBL process. This is in agreement with other authors who have suggested that teachers empower and enhance the design and implementation process based on their knowledge of the subject area, feedback, practical experiences (Abudu & Mensah 2016; Konokman et al. 2017), and the needs of their students based on their context (Alsubaie 2016). While higher competency in developing and implementing a curriculum seems to be related to years of experience, it is counterbalanced by teachers with less experience and more exposure to recent research and insight related to curriculum. Thus, teachers' seniority does not affect teachers' perceptions and competencies in curriculum development and implementation (Badri et al. 2016; Konokman et al. 2017).

Theme 5: Collaboration and involvement can assist in the development and implementation of RCD-PBL curricula.

Collaboration among peers and the involvement of the teachers has helped to a large extent and was cited as “crucial” in the development and implementation of RCD-PBL curricula by all the respondents. In planning and delivering RCD-PBL educational units to students, all teachers (100%) cited collaboration and teamwork among peers as a critical component strength. This showed that all the science faculty in education members collaborated to write the RCD-PBL curriculum.

Collaboration among teachers has enabled sharing of ideas and experiences and the involvement of the teachers was important as they are the ones familiar with their student's interests, needs, and knowledge gaps. The theme is in line with the National Institute for Excellence in Teaching (2020), which suggested that having a high-quality curriculum that impacts students' outcomes depends on the successful implementation and member involvement (school leaders and educators) in designing, delivering, and supporting the curriculum. As a result, teachers' participation in the curriculum design process and understanding of how the curriculum's fundamental elements are aligned is pivotal. Being key factors and part of the environment that affects curriculum implementation (Alsubaie 2016), teachers impact students' outcomes in addition to instructional timing, subject, location, and technology support (Chen and Yong-Cih, 2019), as they are the main points of contact with the students in terms of catering their needs and delivering the instruction and curriculum programs successfully (Hattie 2012; Sahli 2017). In addition, the collaboration among all teachers across campuses resulted in building curriculum units with rigor taking into consideration the culture, context, interest, and needs of second language learners' students as well as ensuring the vertical and horizontal alignment of these PBL units as reported in the interviews. According to the respondents, this was due to the constructive feedback they received from RCD leaders and coaches which further enhanced their understanding of how components are aligned. This was supported by Edmunds et al. (2017) who have highlighted that the rigor in delivering PBL curricula is associated with teacher involvement and collaboration in designing the curriculum along with the project within its units. This theme addressed Ergul and Kargin's (2014) recommendations in terms of developing a curriculum that centralizes around PBL by involving teachers and ensuring collaboration, and interaction between teachers as well as a selection of contextual real-life project topics for students.

Theme 6: RCD-PBL curriculum can contribute to improvement in MAP scores

Based on the responses of the participants, findings showed that all respondents agreed that RCD-PBL contributes to an increase in students' achievement and MAP scores. Similar findings were obtained from the quantitative analysis of SSKT and MAP growth scores in this study. In addition, respondents have clarified the importance of PBL curricula and their positive effect on students in understanding various scientific concepts through authentic projects. They have mentioned that RCD-PBL GRASPS tasks helped in addressing each student's academic level through differentiated products and approaches supported by teachers and peers. As a result, teachers stated that this type of curriculum will play an important role in improving students' knowledge and skills thus enhancing their achievements in international exams. According to teachers, this enhancement is due to the alignment that the RCD has offered between standards, instructions, and the type of assessment used. Based on the NGSS framework, delivering science using the PBL approach allowed students to deeper their knowledge and understanding of concepts, and enhanced their skills by reaching grade-level expectations through authentic and meaningful projects (Simpson, Sunder & Gabler 2017; Holthuis et al. 2018).

Respondents specified that while the RCD-PBL engaged students in authentic performance tasks (GRASPS) that helped them to transfer their knowledge and improve their skills and achievements, various reasons were given for no/weak improvement in MAP results, from lack of parental involvement to English being a barrier as a second language. Recommendations were given for improving the MAP scores, which ranged from enabling text to speech to acquiring more support from the admin team and parents' involvement to working together with the teachers. In addition to reflecting on the curriculum units, which were mentioned by several researchers (Sanders, Wright and Horn, 1997; Konokman *et al.*, 2017), as means for successful implementation, improvement, and impact on students. Aldabbus (2018) suggested that parents' involvement and collaboration may help greatly in the success of the educational process. Additional informative sessions with effective communication should take place between teacher-school-parents to prevent some parents from either doing the projects for their children or being unsupportive and negligent towards their children's needs. Also, parental involvement and support will increase students' motivation and allow them to take MAP tests

seriously by checking students' progress and improvement from year to year in comparison to their cohort whether in the district, nationally, or internationally.

Finally, the questionnaire respondents have positive perceptions of RCD-PBL, whereby some were initially hesitant to let go of their students and adopt the student-centered approach, which is more engaging and relevant to solving real-world problems with students using their learning skills such as collaboration, critical thinking, and communication. Also, the way that respondents perceived PBL has changed, and they now seem to have more confidence and faith in it as seen in their statements. Moreover, the positive results and outcomes observed in the SSKT and MAP confirm teachers' perceptions towards the alignment between the current intended written curriculum (student-centered), the implemented and the assessed (attained) curriculum as observed through their responses in the questionnaire which reflect the foundation of our conceptual framework (van den Akker & Voogt 1994). Such a curriculum leads to higher achievement in different cycles and subjects as advocated by several researchers (Polly et al. 2015; Üzümlü & Pesen 2019). Thus, results of the third research question analysis have shown that while the RCD-PBL curriculum science units had a positive impact on teaching and learning and largely impacted the students and affected their achievements and MAP scores, teachers' involvement, receptivity, readiness, and willingness were fundamental factors for developing and ensuring proper implementation and success of this curriculum design and educational approach regardless of the challenges faced.

5.3 Conclusion

Achieving an outstanding quality in education is one of the most important pillars of the UAE centennial plan. While the UAE government has concentrated its efforts and dedicated significant resources to reshaping its economy, moving from a market-based to an innovative knowledge-based economy is closely linked to meeting and acquiring the demands and skills of the twenty-first century, which are pivotal to changing the procedures, structures, and practices of current schools to make teaching and learning more relevant. Unfortunately, the recent trend in UAE students' achievement in benchmark and international tests has shown a downfall in scores specifically in science whereby the curriculum is heavily focused on the memorization of concepts (teacher-centered) rather than the construction of knowledge (student-centered), thus affecting the aspiration and the country's vision and plans. Therefore, since students' experiences with science in school are influenced by teachers' pedagogical approaches, and how

science is delivered and assessed, and by following the lead of other innovative-based economies such as Finland, a viable cohesive, and sustainable curriculum centralized around PBL built on the Rigorous Curriculum Design (RCD) framework and developed by teachers is required to ensure a contextual, cultural, and work-driven demands of second language learners. Such a curriculum should be capable of closing the gap between what and how students are learning and how they are applying the information and skills in real-world settings.

While Project-based learning (PBL) has been established, recognized, and implemented in schools to varying degrees for many years, particularly in North America, Europe, and some of Western Asia, very few schools in the Middle East and North Africa (MENA) areas are now adopting the PBL approach for certain year group levels, courses, or for off-curriculum time. Although PBL aims to: involve students more deeply in the learning process of subjects they have never studied before; increase knowledge retention; improve academic results; and enable them to be lifelong learners, few research studies on its implementation and the evaluation of its efficacy once centralized in the curriculum on students' achievements have been conducted in the MENA region. Furthermore, the new curriculum cannot be fully implemented if the teachers' (one of the main stakeholders) disagree with its premise, do not comprehend its significance and intent, and do not modify their initial perceptions towards such curriculum. As a result, the implementation will only provide a minimally effective outcome. Thus, the purpose of our study was to Investigate the effectiveness and teachers' perceptions of RCD for PBL implementation on middle school science students' achievement and Measure of Academic Progress (MAP) scores in Abu Dhabi, UAE.

In lieu of the purpose of this research, and looking over the SKKT results, MAP growth scores, teachers' questionnaire survey, and teachers' interviews sessions key finding, it can be concluded that the RCD-PBL implementation is effective and has increased the middle school science students' achievement scores in the science standardized knowledge test. Moreover, RCD-PBL implementation has improved the MAP growth scores for all middle school students whether in grades 6, 7, or 8, thus affected positively the science results of the students in external assessment. In addition, teachers' perceptions towards Rigorous Curriculum Design for project-based learning development, implementation, and effectiveness in sciences have been positively affected, evolved, and changed for the better. They have emphasized the significance of their engagement and cooperation with specialists and curriculum developers that RCD brings

together as a component that contributes to the development of a high-quality comprehensive curriculum. Teachers have also highlighted the importance of their involvement and understanding of the development and implementation process of the RCD-PBL science curriculum units. It is through continuous professional development on the RCD, PBL, and NGSS that they have gained the needed skills and acquired a clear understanding of the relationship and alignment between the standards, instructions, and assessment which gave them a realistic, step-by-step complete roadmap to successful development and implementation. Also, while collaboration with other members has allowed teachers to build and plan a rigorous curriculum which reduces the planning time, their subject knowledge and competencies have allowed them to be flexible, and more confident in the way they deliver the materials and accommodate these units to meet the needs of their students. In addition, Teachers pinpointed that the PBL units and authentic tasks (GRASPS) built using the RCD were a successful approach for teaching and learning science because they are student-centered, relevant, authentic, and more engaging than textbook-based curricula especially since they help students develop skills and permit their knowledge transfer but allowing them to take part and solve real-world problems. Furthermore, teachers now have more trust in the PBL curriculum units' implementation process since they have observed its favorable effects on students' academic performance (achievement) and overall development. While teachers noted some obstacles and challenges when attempting to implement the PBL units for the first time, including changing parents' perceptions about assessment type, difficulty in changing students' routines and mindsets, the need for higher levels of thinking and analysis, planning differential learning activities jointly, fear and reluctance, time management, letting go of students, changing teaching methodology, and reverting back to the old teaching an approach, most of these obstacles faded and were solved over the implementation time and by the help and support of the coaches and coordinators. However, parental involvement, and support is still an area of improvement that the school and researchers need to focus and work on as it will allow the students to accommodate to the new approach and allows them to achieve better results by that students' mindset and attitude will change over time.

5.4 Future Research Recommendations

Investigating the effectiveness and teachers' perceptions of RCD for PBL implementation on middle school science students' achievement and Measure of Academic

Progress (MAP) scores in Abu Dhabi, UAE was the main priority of the current study. Looking at the study's key findings and results, several future research recommendations were to be considered. First and foremost, it would be beneficial to expand the outcomes of the study by including other subjects such as Mathematics and English and grade levels as another recommendation for future research to measure the effectiveness of RCD-PBL on students' achievement in all the subjects and grade levels that are required to conduct the MAP exam. As well as study the effect of non-intellectual factors that might impact students' achievement and readiness for STEM, based on gender, when the PBL curriculum is implemented since male and female students outperformed each other's in different grade levels. Moreover, additional studies should focus on the recipient of knowledge (students' perceptions) rather than the practitioners of instructions (teachers' perceptions), which was the focus of this study, as their opinions and recommendations provide valuable feedback that should be considered in the reflection process in order to enhance the assessment, instructions, and delivery of these type of units. Also, their point of view towards the implementation of such approach compared to the traditional one should be collected. Furthermore, grasping parents' perceptions as well as exploring and understanding their points of view and recommendations towards the effectiveness of RCD-PBL will ensure their involvement and support in this process, thus leading to better students' results. Finally, while many US districts have implemented Ainsworth's RCD framework for decades, creating PBL units using this model and expanding the context of it is implementation to the MENA regions and other Emirates than Abu Dhabi could be one of the future recommendations. As such research will allow us to compare where and why this process is working better in one Emirates than in others or even between one country and another. Also, allow the researcher to examine what are the contributing factors that ensure the successful implementation of RCD-PBL units within these contexts.

5.5 Implications

The findings of this research study have several implications for the education sector (teachers, students, and administrators); parents, and the Government. First and foremost, the findings of this study have demonstrated the significance of the RCD-PBL curriculum in raising middle school science students' SSKT scores in a private school in Abu Dhabi, UAE. Secondly, the results have also shown that the RCD-PBL curriculum improves middle school science students' MAP scores in this school. Additionally, the outcomes have demonstrated the

suitability of the RCD-PBL model for the UAE since it takes students' culture, beliefs, and values into account. Such results should also encourage policymakers and the Government to continue to train teachers and continue implementing the RCD-PBL curriculum by also availing more resources and having awareness programs that will inform the parents, community, and industry on the importance of this initiative in terms of molding a student who has the skills and knowledge to solve real-world problems. From the feedback obtained from this study, it is evident that more parental involvement and support in the RCD-PBL process is required for more effectiveness and successful implementation of the process. In addition, teachers' support by school administrators is also of paramount importance as they are the key drivers and implementers of the RCD-PBL process. Therefore, more support should be availed for teachers to come together, with their team leaders and coaches to reflect on the RCD-PBL process after a while. The administrators should frequently monitor and evaluate the RCD-PBL to determine the hindrances, and difficulties, and whether the RCD-PBL is achieving its aim and objectives. Additionally, the decline of students interested in pursuing science education over the past ten years raises serious concerns for the future of the STEM workforce as it will become more and more difficult to fill STEM roles (OECD 2006; Potvin & Hasni 2014). As a result, and given that the RCD-PBL curricula under investigation are based on the NGSS, this study may be a crucial step in ensuring that teachers and students are prepared to manage STEM-based curricula that are primarily focused on PBL while also increasing students' engagement and accomplishment levels in science classrooms and external examinations. Moreover, since this study is being conducted at an Emirati school in the United Arab Emirates that is spread across five different emirates, other sister schools may be able to use the findings and benefits of this study. Furthermore, as this study investigated the efficacy and teachers' perceptions towards their involvement in the development and implementation of such curriculum, this study could provide a new perspective towards curriculum design, that might be an eye opener to other MENA countries to adapt. Especially, that limited studies were done on the RCD in the United States although it has been used for more than a decade in some schools as highlighted by Ainsworth & Donovan (2019). Finally, the results and implications of this study can help support the UAE educational reform, which aims to improve the quality of education in the UAE. In addition to paving the way to achieving the UAE National Agenda 2071 of being the top educational country in the world.

5.6 Limitations

The present research study has some limitations that might lead to constitute new opportunities for additional inquiries. The first limitation is related to the teachers' classrooms which needs to be observed and considered in future research to collect further information about the implementation of RCD-PBL in the classrooms to make sure that students are acquiring knowledge and constructing and developing the needed skills through the unit GRASPS task. The second limitation is linked to the interview participants' sample size of the study. The sample size was small due to the limitation of accessing and implementing such initiative in other sister schools, as well as taking their consent. The third limitation is connected to the grades and the subject selected which are limited to middle school students and the science subject only. Therefore, the results will be more focused on the middle cycle and specifically science. Moreover, another limitation is related to the length of the study. While one academic year allowed us to evaluate the initial impact and effectiveness of such curriculum units, evaluating its impact over the course of three years will allow us to better evaluate the impact of a new educational approach.

5.7 Concluding note

Limited number of studies of this nature have been done before, to investigate the effectiveness of the RCD-PBL implementation on students' achievement in SSKT and MAP scores in middle school science classrooms. This study has contributed to research by using statistical methods to quantitatively analyze pre-test and post-test SSKT scores data and MAP scores to determine the effect of the RCD-PBL curriculum on middle school science students from private schools in Abu Dhabi, UAE. Designing a questionnaire which was uploaded and analyzed in SPSS, to investigate the middle school teachers' perceptions and their demographics towards rigorous curriculum design for project-based learning development and implementation in science. Qualitative analysis using thematic analysis was done in QDA Miner Lite, with the intention also to investigate middle school teachers' perceptions towards RCD for PBL learning development and implementation in science. The results of this study will inform key stakeholders in the education sector on the effectiveness of the RCD-PBL curriculum as opposed to the traditional textbook-focused curriculum. This study will inform stakeholders on what teachers feel about the RCD process itself, the training and challenges, hindrances and

difficulties, impact, and benefits, and above all its impact on SSKT and MAP scores in middle school science students in Abu Dhabi, UAE.

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APPENDICES

Appendix A: Sample of one RCD-PBL Grade 8 Science Unit on Energy, Forces, and Motion.

Key concept	Related concept(s)	Global context & Exploration
Relationships : Relationships in sciences indicate the connections found among variables through observation or experimentation. These relationships also can be tested through experimentation. Scientists often search for the connections between form and function. Modelling is also used to represent relationships where factors such as scale, volume of data, or time make other methods impractical.	Function : A purpose, a role or a way of behaving that can be investigated; a mathematical relationship between variables. Movement : The act, process, or result of displacing from one location or position to another within a defined frame of reference.	Global Context: Scientific and technical innovation Exploration: process and solutions
Statement of inquiry		
CONCEPTUAL UNDERSTANDING: Relationships exist through functions and movements. STATEMENT OF Inquiry: Relationships between functions and movements can be used to design processes and solutions		
Inquiry questions		
Factual: What is movement? How is the objects movement related to force? What processes need to be considered when designing new solutions? Conceptual: What types of relationships are established through functions and movements? Debatable: Does every problem have an ideal solution? (Is there a perfect design?).		

Objectives	Summative assessments	
Criterion A: Knowing and Understanding ii. Apply scientific knowledge and understanding to solve problems set in familiar and unfamiliar situations Criterion C: Processing and Evaluating i. present collected and transformed data ii. interpret data and describe results using scientific reasoning v. describe improvements or extensions to the method Criterion D: Reflecting on the impacts of science i. describe the ways in which science is applied and used to address a specific problem or issue ii. discuss and analyse the various implications of using science and its application in solving a specific problem or issue iii. apply scientific language effectively iv. document the work of others and sources of information used.	Outline of summative assessment task(s) including assessment criteria: GRASPS Performance Task: supply pods Goal- Design a solution using knowledge of forces and motion to minimize damage and waste when dropping supply pods Role- You are a mechanical engineer working for UAE red crescent foundation. Audience- Your audience is the board of directors at UAE red crescent foundation. Situation- The UAE red crescent foundation is the UAE's main relief and aid agency that provides relief during natural disasters. One way it does this is by using helicopters to drop emergency supplies in areas that have been affected by natural disasters like earthquakes or floods. The emergency supplies must be packed in containers called supply pods that protect the supplies as they hit the ground. The UAE red crescent foundation has issued a Request for Proposals (RFP) for the development of supply pods to hold emergency supplies as they're delivered to people in need. Successful proposal designs will address the following three criteria: : 1. Minimize cargo damage. 2. Maximize shell condition 3. Keep costs low In addition to meeting the above criteria, the design of the supply pod should take into account the constraints, or limits to the possible solutions. These constraints include: • Supply pod must be delivered by helicopter. • Supply pod must be dropped from the same height for each test Product- Proposal form for finalized SupplyPod Design This GRASP task thoroughly summarizes the design request and describes the proposed design by listing the details of multiple design tests and the final results. The process embeds multiple pieces of strong evidence to support design decision, thoroughly explaining why the specific feature was selected over other options and how that feature of the design relates to the criterion. Standards Next Generation Science Standards (NGSS) NGSS Practices Practice 1: Asking Questions and Defining Problems Practice 2: Developing and Using Models Practice 8: Obtaining, Evaluating, and Communicating Information NGSS Disciplinary Core Ideas PS2.A: Forces and Motion:	Relationship between summative assessment task(s) and statement of inquiry: Students identify the relationship between impact force and collisions when coming up with solutions to create and model a SupplyPod that can move from a helicopter to the group with minimal cargo damage, maximum shell condition whilst at the same time keeping costs as low as possible. Through a series of tests, students can revise their initial designs and make changes before selecting their final solution to the problem.

	For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's third law). (MS-PS2-1) PS2.A: Forces and Motion: The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion. (MS-PS2-2) ETS1.A: Defining and Delimiting Engineering Problems: The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions. (MS-ETS1-1) ETS1.B: Developing Possible Solutions: Models of all kinds are important for testing solutions (MS-ETS1-4) Disciplinary Core Ideas: ETS1.A; ETS1.B; ETS1.C PS2.A; PS2.B NGSS Crosscutting Concepts Structure and Function	
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Appendix B: RCD Process

Designing Rigorous and Relevant Units of Study (Curriculum, Assessment, Instruction)

Part 1: Prioritize the Learning Targets
Process Steps and Primary Tasks
Align the priority and supporting Standards CCSS to the learning objectives in the MYP Programme per year level. ☐ Use standards and indicators to deepen understanding of grade level performance expectations ☐ Cluster the priority and supporting standards according to topics to view through a conceptual lens to reach conceptual understanding in the MYP ☐ Sequence the clustered priority and supporting Standards throughout the year (Curriculum Map/Scope and Sequence)
Review/Revise/Create Statement of Inquiry: Identify Key concepts and Related Concepts ☐ Choose one key concept and two related concepts ☐ Choose one of the global contexts with one exploration. ☐ Write your statement of inquiry
Develop Inquiry Questions ☐ Inspired by the statement of inquiry develop Factual, Conceptual, Debatable questions (this will help scaffold the objectives that students strive to achieve)
☐ Confirm that every priority and supporting standards is assigned to a unit of inquiry and vertically aligned throughout the Programme of Inquiry. ☐ Create a subject yearly overview includes all mapped standards per each year level.
Part 2: “Unwrap” the Priority Standards
Process Steps and Primary Tasks: These can be found in the CCSS ACHIEVE FLIPBOOKS
☐ “Unwrap” the priority learning targets for each unit of study to determine the specific concepts (Noun) and skills (Verb) (ATL skills) and examine what students need to <u>know</u> and be able to <u>do</u> as a priority.
☐ Assign success criteria to each priority learning target.
☐ Determine the degree of rigor (cognitive level) for each skill by identifying its approximate level (1-6) of revised bloom’s taxonomy. (verb) (command terms)
☐ Determine the topical big ideas (foundational understandings) derived from the concepts for that instructional unit. (Noun)
☐ Select the specific academic vocabulary students will learn during the unit.
☐ Establish interdisciplinary connections.
Part 3: Create a Pacing Calendar
Process Steps and Primary Tasks
☐ Determine the approximate number of weeks needed to teach and assess individual unit (20 -24 H recommended by the IB)
☐ Decide the sequence in which to teach and assess these units as they relate to time, other activities. (yearly subject overview)
☐ Design a matching timeline or pacing calendar to schedule these instructional units, considering required assessment schedules for NWEA MAP (Fall, Winter, Spring), and common assessments.
☐ Extend pacing calendar to the end of the school year to ensure that all students will be prepared to enter the next grade with the priority learning targets as “assured mastery”.

Part 4: Create Unit Assessments (Pre-/Post-/”Dipsticks”)	
Process Steps and Primary Tasks	
☐	Create the end-of-unit post-assessment matched to the Priority Learning Target and appropriate assessment method using appropriate year level MYP criteria
☐	Post assessment needs to be directly linked to the statement of inquiry.
☐	Create the pre-assessment aligned to the end-of-unit post-assessment.
☐	Align the end-of-unit post-assessment with benchmark assessments and end-of-unit exams.
☐	Plan shorter, progress-monitoring checks (in-class checks for understanding: “dipsticks”) aligned to the end-of-unit post-assessment for use throughout the unit.
Part 5: Plan Rigorous and Relevant Learning Engagements	
Process Steps and Primary Tasks	
☐	Design engaging classroom performance tasks with task-specific scoring guides—based on the “unwrapped” concepts and skills—apply the standards in a relevant and real-world, authentic context Using the MYP criteria.
☐	Identify research-based effective instructional strategies to teach the unit.
☐	Identify differentiation strategies (Response to Intervention/Scientific Research-Based Interventions)
☐	Select the appropriate instructional resources and needed materials that will best prepare students to learn the “unwrapped” concepts, skills and Big Ideas, and prepare for the end-of-unit assessment, the resources and text used should lead to global mindedness.
☐	Plan enrichment and remediation activities to address the diverse learning needs.
☐	Launch the unit and utilize shorter, progress monitoring checks throughout the unit—aligned to the end-of-unit post-assessment—to inform, modify, and adjust instruction.
☐	Motivate, engage, and empower learners to track and monitor progress of Priority Learning Targets.
☐	Provide exemplars and descriptive feedback on learning goals and facilitate peer/self-assessments
☐	Plan opportunities for student agency, initiative and service as action.
☐	Monitor/report attainment of Priority Learning Targets through sound grading/communication system.
Part 6: Pre-Assess, Analyze Data, Teach the Unit, Post-Assess, Analyze Data	
Process Steps and Primary Tasks	
☐	Administer the pre-assessment (classroom or common).
☐	Score and analyze student data <u>individually</u> or in grade-level <u>Data Teams</u> to determine needs.
☐	Facilitate data conversations with students. Expect students to track/monitor proficiency attainment.
☐	Decide how to differentiate instruction for specific students based on <i>assessment evidence—including the enrichment of those students who are already proficient.</i>
☐	Begin teaching the planned instructional unit of study, flexibly group students according to needs.
☐	Conduct frequent, formative progress monitoring checks to determine student understanding.
☐	Differentiate instruction to meet identified learning needs <u>throughout</u> the unit.
☐	Administer end-of-unit classroom or common formative post-assessment.
☐	Score and analyze student data <u>individually</u> or in grade-level or course-specific <u>Data Teams</u> .
☐	Schedule a “buffer week” in which to re-teach differently, any students still not proficient by <u>end</u> of unit AND enrich those students who are proficient and advanced; reassess non-proficient students.
☐	Repeat process for <u>next</u> instructional unit of study!

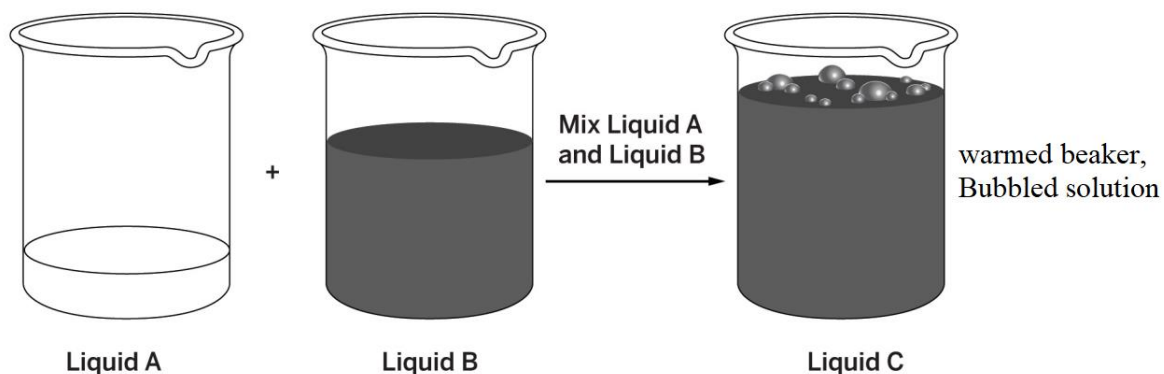
Adapted by MVedra/ MRomke/VGammoh/NAssaf from 2009 Larry Ainsworth – Rigorous Curriculum Design

Appendix C: Sample of One Pre-Post Science Standards Knowledge Test

Changing Properties of Matter

Recall your knowledge regarding changing properties of matter to answer each of the following multiple-choice questions.

1. What physical property could you use to determine the difference between iron and steel?
 - a. color
 - b. flammability
 - c. density
 - d. oxidation (rusting)
2. Which of the following is a chemical property of matter?
 - a. gasoline is flammable
 - b. Barium melts at 725°C
 - c. Density
 - d. an apple is red
3. Which of the following is NOT a physical property of matter?
 - a. Gold density is 19.3 g/mL
 - b. Water freezes to ice at 0 °C
 - c. Rusting of a bicycle
 - d. Salt dissolves in water
4. Density is represented by:
 - a. Mass x Volume
 - b. Mass ÷ Volume
 - c. Weight x Mass
 - d. Volume ÷ Mass
5. Balancing a chemical equation happens when changing:
 - a. the products.
 - b. the coefficients.
 - c. the reactants.
 - d. the subscripts.
6. Sheikha wanted to identify whether a chemical reaction has occurred when clear liquid (A) was mixed with a dark liquid (B).



The mixture (C) formed got warm and bubbled. Below are some data collected by Sheikha:

	Color	Mass (grams)	Density (grams per cubic centimeter)	Burns in air
Liquid A	colorless	26	0.98	yes
Liquid B	black	85	1.25	yes
Liquid C	black	110	1.45	yes

Based on Sheikha's data, did a chemical reaction occur?

- No. The color of Liquid C is the same as Liquid B, so they are the same substance.
- No. Liquid B and Liquid C both burn in air, so they are the same substance.
- Yes. Liquid C has a different density than Liquid A or Liquid B, so a new substance has formed.
- Yes. The mass of Liquid C is not the same as Liquid A, so a new substance has formed.

7. Seif has two clear, colorless liquids, Liquid 1 and Liquid 2. He needs to determine whether the two colorless liquids are the same substance. Below is the information given to Seif:

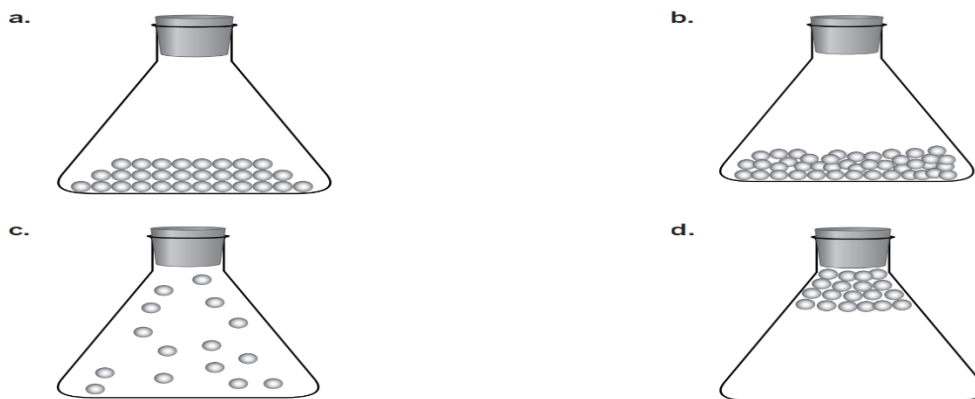
	Structure	Molecular Weight	Volume
A		60 grams per mol	100 milliliters
B		60 grams per mol	50 milliliters

Based on the information in the table, are Liquid 1 and Liquid 2 the same substance?

- No, Liquid 1 and Liquid 2 have different volumes.

- b. Yes, Liquid 1 and Liquid 2 have the same molecular weight.
- c. Yes, the molecules of Liquid 1 and Liquid 2 have the same number of atoms.
- d. No, the atoms of the molecules of Liquid 1 and Liquid 2 are arranged differently.

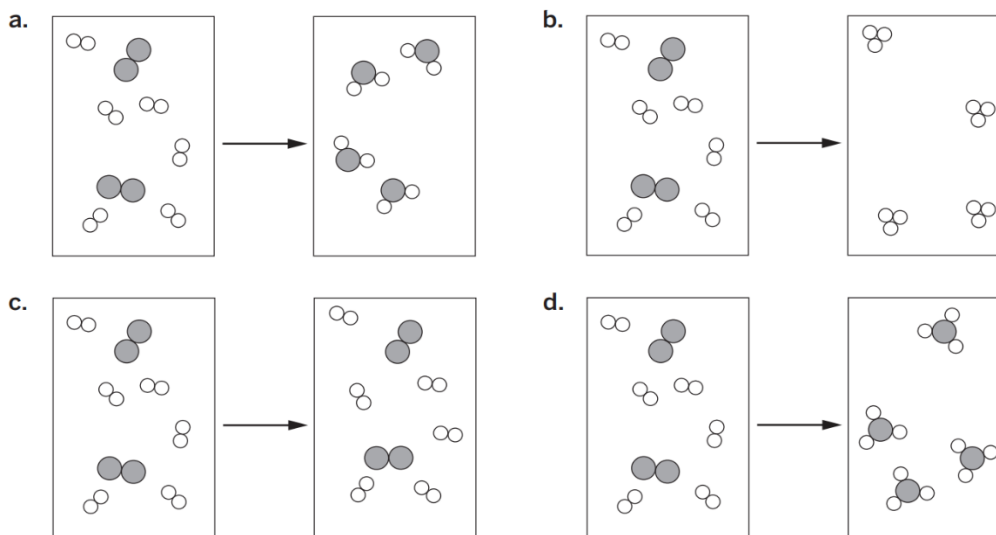
8. Fahed has just finished studying various forms of matter. His teacher asked him to draw a model that represents their observations of the different forms. Which of the model submitted below best represents what happens to gas molecules in a closed container?



9. $\text{MgO} + 2\text{HBr} \rightarrow \text{MgBr}_2 + \text{H}_2\text{O}$

- a. Reactants: MgO , HBr Products: MgBr_2 , H_2O
- b. Reactants: MgBr_2 , H_2O Products: MgO , HBr
- c. Reactants: MgBr_2 , MgO Products: HBr , H_2O
- d. Reactants: MgO , H_2O Products: MgBr_2 , HBr

10. Which of the model best represents conservation of matter in a chemical reaction?



11. Ms. Emma has placed ice cubes in a beaker. She sets the beaker on a hot plate and as expected, the ice turns into water then boils, producing steam. Soon, all of the water appears to be gone.

Ms. Emma asks the students if it's possible for the molecules in her demonstration to eventually stop moving.

Which of the following student responses is the most accurate?

- Molecules can stop moving once the temperature change has resulted in a solid becoming a liquid.
- Molecules can stop moving once the temperature has reached the coldest temperature possible.
- Molecules will never stop moving because the temperature is always.
- Molecules will never stop moving because the temperature remains the same

Identify the number of atoms that exist in each ionic compound using your scientific knowledge.

12. How many atoms of Oxygen(O) are in $\text{Ba}_3(\text{PO}_4)_2$?

Apply your scientific knowledge and understanding to solve below questions and problems.

13. Look at the picture of the density column. Which liquid has the highest density?

- Baby oil
- Chocolate syrup
- Vegetable oil
- Whole milk



14. Wadima was conducting an experiment. In the experiment she poured 32 mL of water into a graduated cylinder. Then she added a metal shaped object with a mass of 6.7 grams to the graduated cylinder. The cylinder's final volume is now 38.6 mL. **Calculate the density of an irregular shaped object.** (Show your Work)

Apply concepts to make scientifically supported judgments.

15. Use the table and your knowledge of science to answer the questions. The main compound of natural gas is methane. When methane reacts with oxygen gas, carbon dioxide and water vapor are produced, this is called combustion reaction.

Compound	Formula
Carbon dioxide	CO_2
Methane	CH_4
Oxygen	O_2
Water	H_2O

- (1) Write a balanced equation for the combustion of methane. (show your work)

- (2) Explain if burning of methane is a chemical or physical change and why?
- (3) What would happen if the subscript of a chemical compound was changed

Appendix D: Teachers' Questionnaire Survey and Consent Form

Dear Teachers,

This consent form section is only part of the ethical process for fulfillment of Ph.D in Education at the British University in Dubai, This section should give you an idea of what the research is about and what your participation will involve. Kindly take the time to read this form carefully and to understand any accompanying information. Shall you require more details or clarifications towards some additional information mentioned or not included in this section, please reach out to noura_assaf@hotmail.com.

Research Purpose

The purpose of this study is to investigate the effectiveness and teachers' perceptions of Rigorous Curriculum Design for project-based learning implementation on middle school science students' achievement and MAP scores in a private school in Abu Dhabi, UAE.

The questionnaire is grasping your perceptions and demographics towards rigorous curriculum design for project-based learning development and implementation in science. It is divided to four parts: demographics, professional development, RCD for PBL receptivity and understanding (alignment and assessment). The questionnaire will take approximately 7 to 10 minutes to complete.

Confidentiality- Anonymity- Security

If you agree to participate in this study, your identity will be kept anonymous and any other personal information that might be gathered or shared during this research study will be kept strictly confidential and securely stored on a computer and will remain in the personal possession of the researcher and will never be made public without your written consent.

Possible Risks or Costs

There are no known risks if you decide to participate in this research study, nor are there any costs for participating in the study. The information participants provide will help the investigator understand their perceptions towards the rigorous curriculum design for project-based learning development and implementation process in science. The information collected may not benefit you directly, but what is investigated in this study could help future research as well as the education sector.

What your agreement means

Your agreement on this section by clicking “agree” indicates that you have understood the information regarding participating in this research study and agree on taking part in this research as participant. Once you click on “agree”: you will be taken to the questionnaire sections.

Your participation in this questionnaire is voluntary. You have the full right to withdraw from the study at any time without penalty. Your continued participation should be informed as your initial consent, so feel free to ask for clarification throughout your participation.

Part I: Demographics Information				
Gender: ☐ Male ☐ Female Mother tongue: ☐ Arabic ☐ English ☐ Others Campus <i>I currently work at:</i> ☐ Boys School Campus ☐ Girls School Campus Qualifications <i>The highest level of education I hold is:</i> ☐ Bachelor Degree ☐ Master Degree ☐ Higher Diploma ☐ Doctorate	Grade level taught <i>The current grade level(s) that I teach/supervise this academic year:</i> ☐ Grade 6 ☐ Grade 7 ☐ Grade 8 ☐ Grade 9 ☐ Grade 10	Years of Teaching experience in education <i>The total number of years of experience I have including this academic year:</i> ☐ 0-3 years ☐ 4-6 years ☐ 7-9 years ☐ 10-12 years ☐ More than 12 years	Years of Teaching in the school <i>The total number of years that I have worked in this school including this academic year</i> ☐ 1-2 Years ☐ 3-4 Years ☐ 5-6 years ☐ 7-8 years ☐ 9 years or more	
Prior American Curriculum teaching/leading experience <i>Before coming to this school, did you work in an American Common Core Based Curriculum School?</i> ☐ Yes ☐ No				
Prior International Baccalaureate teaching/leading experience <i>Before coming to this school, did you teach/lead in an International Baccalaureate Programme?</i> ☐ Yes ☐ No If Yes, which Program(s): ☐ Primary Year Program (PYP) ☐ Middle Year Program (MYP) ☐ Diploma Program (DP)				

Part II-Professional Development

RCD training

Has the RCD training workshop(s) equipped you with the necessary skills to develop or redesign a curriculum?

- ☐ Strongly Disagree
- ☐ Disagree
- ☐ Neither Agree nor Disagree
- ☐ Agree
- ☐ Strongly Agree

PBL training

Has the PBL training workshop(s) supported you to implement such key approach and assessment in your classroom?

- ☐ Strongly Disagree
- ☐ Disagree
- ☐ Neither Agree nor Disagree
- ☐ Agree
- ☐ Strongly Agree

NGSS: unpacking standards training

Has the NGSS training workshop(s) equipped you with techniques to unpack standards?

- ☐ Strongly Disagree
- ☐ Disagree
- ☐ Neither Agree nor Disagree
- ☐ Agree
- ☐ Strongly Agree

Part III- Receptivity

How do you view the Rigorous Curriculum Design roadmap adopted in writing and designing project-based learning unit of study?

Items	Strongly Agree (5)	Agree (4)	Neither Agree nor Disagree (3)	Disagree (2)	Strongly Disagree (1)
1. Flexible					
2. Uncomplicated					
3. Practical					
4. Reasonable workload					
5. Less Work (than previous)					
6. Easy to implement					
7. Confident about the implementation					
8. Aligned with PBL components					

What is your perception towards the project-based learning units developed using the RCD model?

Items	Strongly Agree (5)	Agree (4)	Neither Agree nor Disagree (3)	Disagree (2)	Strongly Disagree (1)

1. The learning experiences and assessments in the units encourage students to work collaboratively with others					
2. Project-based assessment encourage students to contribute to society					
3. The units take into consideration individual differences among students					
4. The units take into consideration Emirati students society and culture					
5. The units allow students to use the knowledge acquired in meaningful real-world contexts					
6. The units develop students' competency in Thinking					
7. The units foster students' own disposition to recognize when and how to use the key competencies and be willing to do so.					

Listed below are key components of the RCD Design process. Please select all the areas that you believe are your strengths in delivering RCD-PBL Instructional Units to students.

- ☐ Planning Engaging and Relevant Learning Activities
- ☐ Writing Standards Based Student Summative Assessments
- ☐ Writing Standards Based Student Formative Assessments
- ☐ Write and Develop project-based assessment that meets the standards
- ☐ Differentiating Student Instruction in the Classroom
- ☐ Student Behavior Management
- ☐ Matching Student Learning Styles to Teaching Strategies
- ☐ Instructional Pacing and Time Management in the Classroom
- ☐ Diagnostic/Prescriptive Teaching
- ☐ Use of Data to Inform Instructional Lessons
- ☐ Use of Technology to Effectively Manage and Deliver Teaching/Learning
- ☐ Collaboration with Colleagues
- ☐ Providing Students with Effective Feedback on Learning

Part IV- Understanding: Alignment and Assessment.

Rate each sentence stem as Strongly Agree, Agree, Disagree, Strongly Disagree or Neither Agree nor Disagree

Items	Strongly Agree	Agree (4)	Neither Agree	Disagree (2)	Strongly Disagree
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	(5)		nor Disagree (3)		(1)
1. There is a direct relationship between the academic content standards to be taught (NGSS), statements of inquiry set, global context to frame classroom inquiry, and direct purposeful learning experiences provided to the student through the unit activities.					
2. There is a direct relationship between academic content standards to be taught (NGSS), and the PBL assessments provided to the student.					
3. There is a direct relationship between the learning experiences provided to the student through the unit activities and the project-based learning assessment used in the unit.					
4. Working through the unit and lesson planning has allowed me to understand the information gained from the assessment and its use in planning the next unit/lesson to be taught.					
5. The learning resources provided in the curriculum, are aligned to the learning activities of the unit/lesson.					
6. The amount of time spent in planning the delivery of instruction is appropriate.					
7. The implementation of the current curriculum reflected the intended written curriculum					
After I taught my first RCD unit, my students demonstrated improved achievement as measured against their attainment on the pre versus post assessments of the unit. Base your response upon the percentage of students that met the standard for the first unit that you taught: ☐ Strongly Agree (greater than 75% of students) ☐ Agree (between 50% and 74% of students) ☐ Disagree (between 25% and 49% of students) ☐ Strongly Disagree (less than 25% of students) ☐ Not applicable					
Rate each sentence stem as Strongly Agree, Agree, Disagree, Strongly Disagree or Not Applicable.					

Items	Strongly Agree (5)	Agree (4)	Neither Agree nor Disagree (3)	Disagree (2)	Strongly Disagree (1)
1. The RCD planning process is student centered.					
2. Project-based learning assessment (GRASPS) used in the units are authentic and relevant to the context of your Emirati Students					
3. Project-based learning assessment (GRASPS) are correlated to the standards and skills that need to be assessed (NGSS)					
4. Project-based learning units and assessment engaged students in problems or questions to make learning more meaningful					
5. Students' voice and Choice are reflected in the unit and assessment.					
6. Project-based learning units developed using the RCD process addresses differentiation of instruction in the unit/lesson planners					
7. The project-based learning units developed using the RCD model ensured coherence in middle school science curriculum that is responsive and relevant to all students needs					
*Modified parts of the questionnaire taken from Sinnema, C. (2011). Monitoring and Evaluating Curriculum Implementation. Ministry of Education, New Zealand. *A 5 point Likert scale has been used to assess the views around the Rigorous Curriculum Design Implementation using Project-Based Assessment with 1= Not Applicable, 2= Strongly Disagree, 3= Disagree, 4= Agree, 5= Strongly Agree. * This survey has been modified and written by a group of RCD training leaders and reviewed by the school director of Education and the general director.					

Appendix E: Teachers' Interview Questions and Consent Form

Teachers' Interview Consent Form

Interview Protocol for middle school science teachers Consent Form

Dear Teachers,

I am contacting you asking your voluntary participation in a study in science education. Please let me introduce myself, and my research.

My name is Noura Assaf and I am a doctoral student in the Science Education Department at the British University in Dubai working under the supervision of Professor Sufian Forawi. The study forms the basis of my doctoral dissertation on "Investigating the effectiveness and teachers' perceptions of Rigorous Curriculum Design for project-based learning implementation on middle school science students' achievement and MAP scores in a private school in Abu Dhabi, UAE". All Middle school science teachers who are delivering the RCD-PBL in grade 6 to 8 classes will know that they are being asked for their input about their perceptions and acceptance in participating in this study. The participation in this interview will involve answering questions relating to your perceptions towards rigorous curriculum design for project-based learning development and implementation in science. The interview will run virtually on Microsoft teams for an hour during professional development time schedule at school. The interview will be recorded to revisit when necessary and eliminate any misinterpretation of the transcript. A copy of the transcript will be shared with you for final review before proceeding to the analysis process. If you choose not to participate or withdraw from the study at any time, there will be no penalty. The information collected from the interview is anonymous and

confidential. Recordings will not be shared with any admin members, and they will only be used for this research purpose and will be deleted once the interviews are transcribed and analyzed. Thank you for being part of this research. I truly appreciate your time and effort in answering the questions for my research. If you have any questions concerning this research study, please contact me on the following email: noura_assaf@hotmail.com

Sincerely,

Noura Assaf

Consent

I ____ (Participant Name) _____ have read and agreed to participate in the research study describe above whereby I will be interviewed by the researcher. I __ (Participant Name) ____ agree on recording the interview session which will not be shared with any admin members, and will only be used for this research purpose only and will be deleted once the interviews are transcribed and analyzed. I ____ (Participant Name) _____ understand that my identity will be kept anonymous and a copy of the transcript will be shared with me by the researcher.

Participant Signature:

Date:

Teachers Interview Questions

RCD MODEL

1. How did the steps offered by the RCD framework help you understand the alignment between standards, instructions, and assessment?
2. How Do you think this framework has helped ensure the vertical and horizontal articulation needed to prepare the students for the international exams and workforce?
3. Do you believe that the RCD process results in the development of high-quality curriculum units?

RCD-PBL IMPACT & EFFECTIVENESS

4. How have RCD-PBL units affected your planning and teaching methods compared to textbook-based curricula planning??
5. What impact did project-based learning assessments have on students' engagement?
6. How did the final product enable students to demonstrate their knowledge and understanding of the science concepts taught within each unit of inquiry?
7. How did the final product allow students to demonstrate their competence in the essential skills set for each unit of inquiry project?
8. How did the final product enable students to understand the relationship between the broad scientific concepts of the unit and the real-world problems?
9. How effective was PBL approach to teaching and learning science?
10. To what extent do you think that these conceptual/contextual projects have increased students' interest and curiosity in science?
11. How were the students interacting with such a curriculum whereby the design, approach, and assessment were different from what they were used to?

RECEPTIVITY & CHALLENGES

12. How has your perception and confidence of PBL evolved since first encountering the instructional model?
13. What did you like the most about these RCD-PBL science units?
14. How relevant were these RCD-PBL science units compared to the textbook curriculum?
15. What hindrances and difficulties did you encounter as you attempted to implement these units?

- Were these challenges overcome through time? How?

PROFESSIONAL DEVELOPMENT

16. How did the RCD/PBL training help you in developing and implementing these PBL units of study?
17. How did the NGSS training sessions help you develop assessments that tackle the performance expectation observable features?
18. How did your knowledge and competencies help you throughout this process?

INVOLVEMENT

19. To what extent do you think your involvement, choice, and collaboration with other colleagues were essential to developing and implementing such a curriculum?
20. To what extent do you think that the collaboration and involvement of teachers towards designing PBL units using the RCD process has reduced the time related to building lesson planners and assessments?

STUDENTS' ACHIEVEMENTS

21. Looking at Fall-Spring MAP data, how did the RCD-PBL curriculum impact the MAP scores results?
 - In case there was no/weak development in students' results, what are the reasons behind that? Any Recommendations?

Appendix F: Institution Acknowledgment Consent Form

October 27th, 2021

To whomever it may concern,

On behalf of [REDACTED], I would like to inform you that we are aware that Ms. Noura Assaf, w [REDACTED], is conducting a research study for the fulfillment of Ph.D. in Education at the British University in Dubai.

We are aware that the purpose of this study is to investigate the effectiveness and teachers' perceptions of Rigorous Curriculum Design for project-based learning implementation on middle school science students' achievement and MAP scores in our school.

We are also aware of the study's procedures and duration, and we have mitigated any potential and foreseeable risks by providing anonymous data for the cohort for which the study will be applied and by ensuring confidentiality and privacy are maintained.

As a school, we support this research study as it will provide insight into the effectiveness of the RCD- PBL initiative on achievement and growth at our school which is a high priority strategic goal for the school and the U.A.E as pertaining to TIMSS and PISA.

Respectfully,

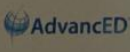
[REDACTED]

Campus Director

[REDACTED]

[REDACTED]

[REDACTED]

Appendix G: Consent Form



Wednesdays, 03 November 2021

To whom it may concern

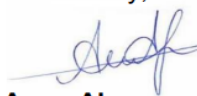
This is to certify that **Ms. Noura Assaf** with Student ID number **20181362** is a registered in the **Doctor of Education** offered by **The British University in Dubai** since **September 2018**.

Ms. Noura has successfully completed her taught modules and is currently working on her thesis titled **“Investigating the Effectiveness and teachers’ Perceptions of Rigorous Curriculum Design for Project-Based Learning Implementation on Middle School Science Students’ Achievement and MAP Scores in a Private School in Abu Dhabi, UAE”**

She needs your support in conducting surveys and interviews to complete her research.

This letter is issued on Ms. Noura’s request.

Yours sincerely,


Dr. Amer Alaya
Head of Student Administration



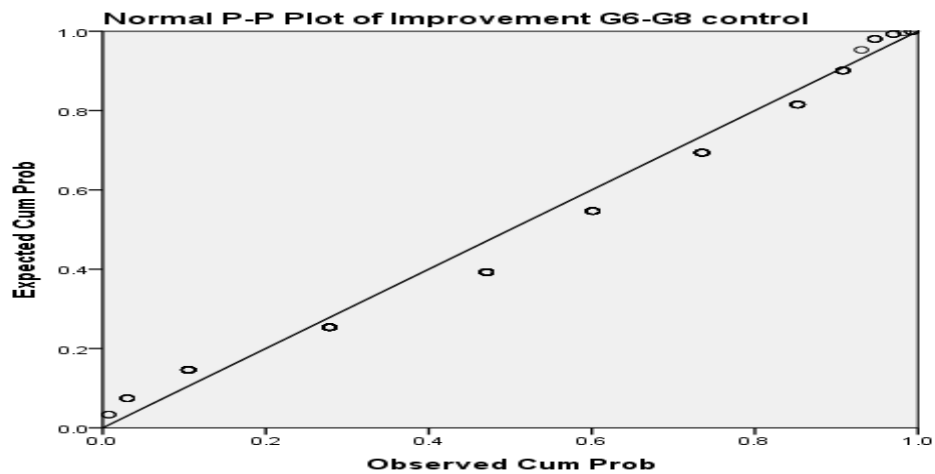
Appendix H: Quantitative Analysis and Normality Tests

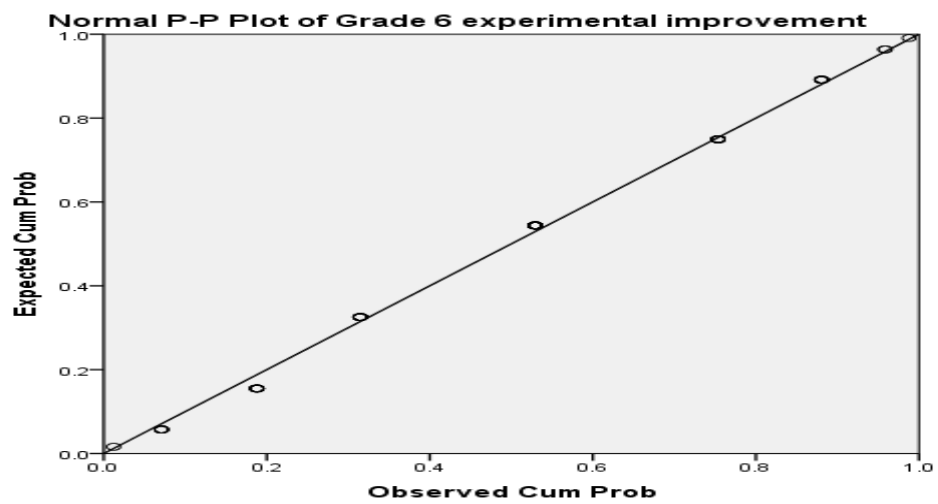
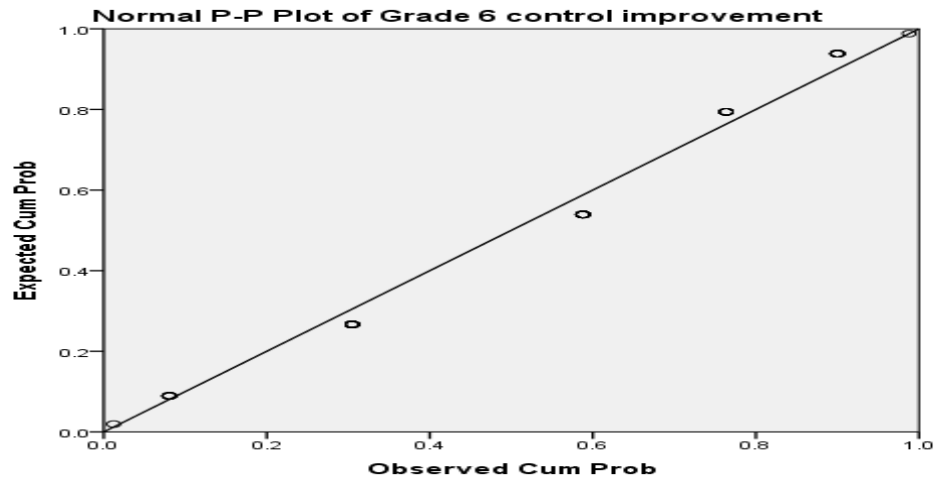
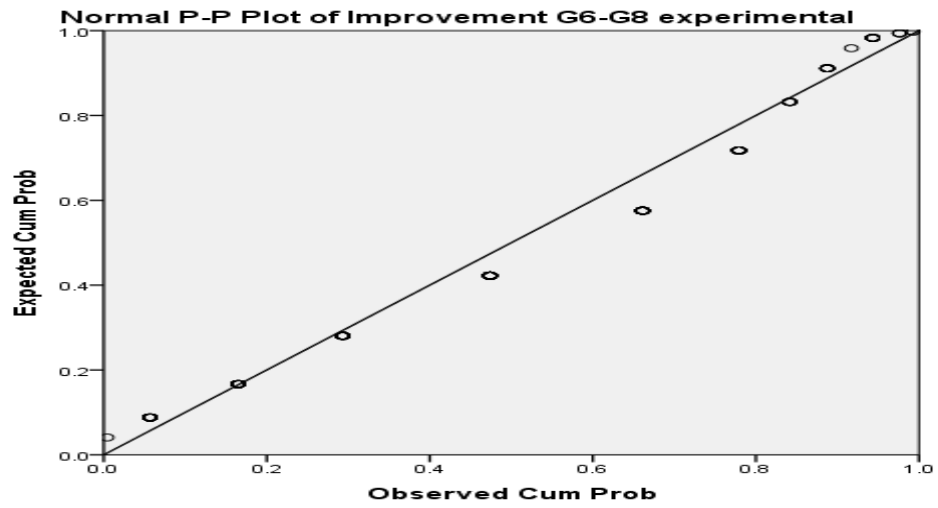
Research Question 1

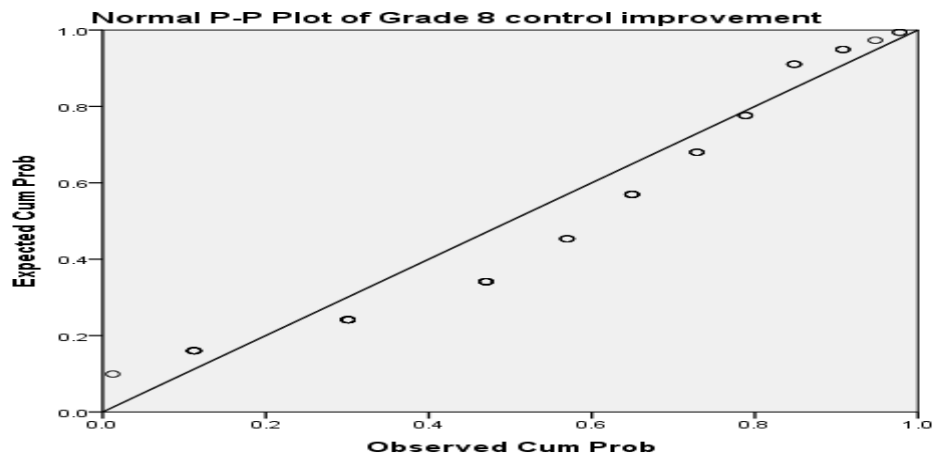
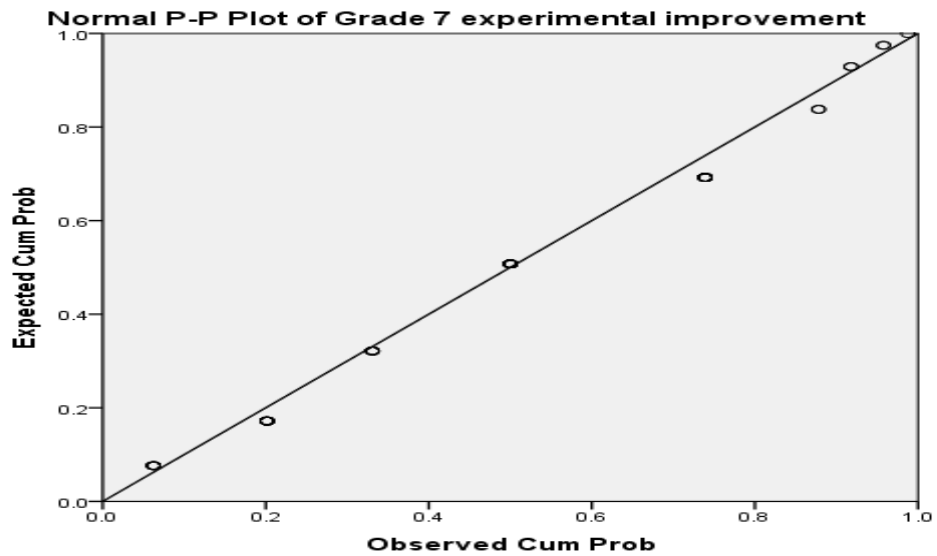
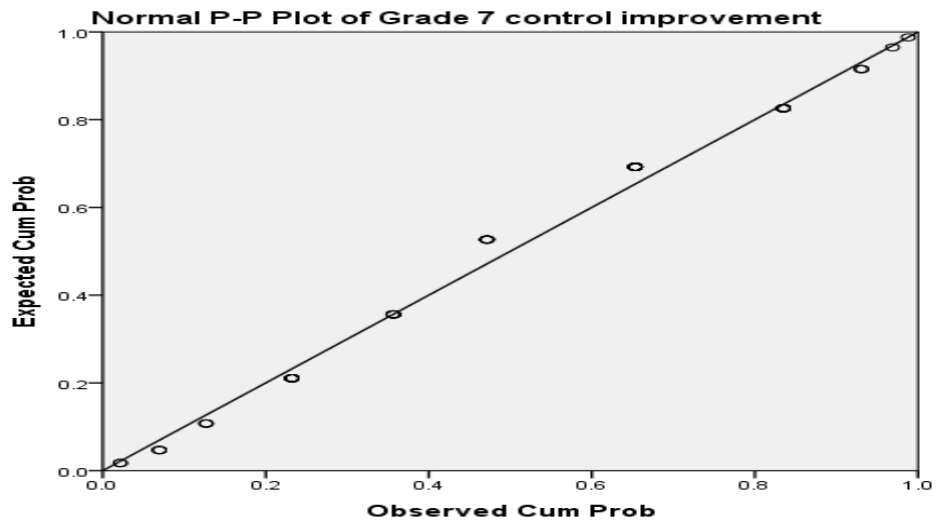
The improvement in SSKT scores and Normal P-P Plot Graphs

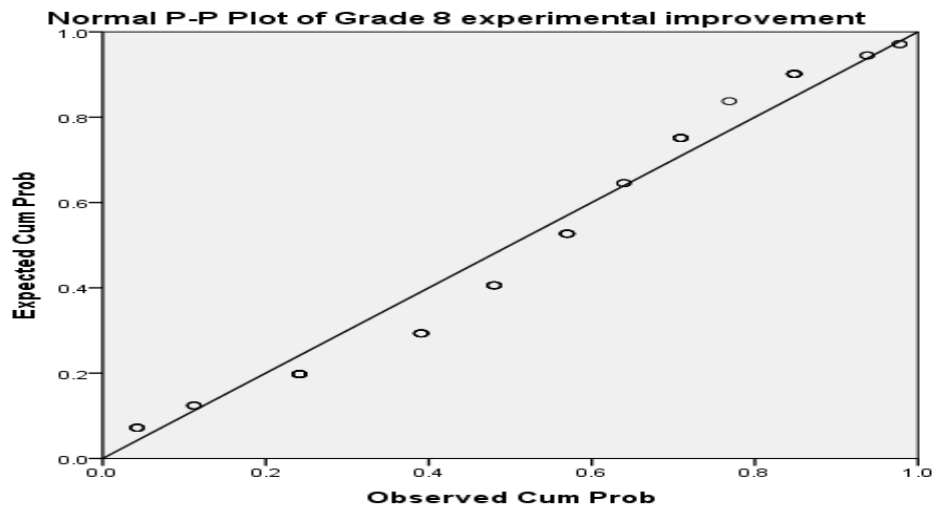
	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
G6-G8 control improvement	.156	153	.000	.915	153	.000
G6-G8 experimental improvement	.163	152	.000	.924	152	.000
Grade 6 control improvement	.196	50	.000	.927	50	.004
Grade 6 experimental improvement	.164	50	.002	.964	50	.125
Grade 7 control improvement	.157	50	.003	.968	50	.200
Grade 7 experimental improvement	.168	50	.001	.921	50	.003
Grade 8 control improvement	.199	50	.000	.880	50	.000
Grade 8 experimental improvement	.147	50	.009	.929	50	.005

a. Lilliefors Significance Correction









SSKT pre and post-test paired-sample t-test with gender

Grade 6 control female SSKT pre and post-test

Tests of Normality

	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Paired difference G6 control female	.194	26	.013	.911	26	.027

a. Lilliefors Significance Correction

Paired Samples Statistics

	Mean	N	Std. Deviation	Std. Error Mean
Pair 1 Pre-test/15	8.154	26	2.9215	.5730
Post-test/15	10.923	26	2.2965	.4504

Paired Samples Correlations

	N	Correlation	Sig.
Pair 1 Pre-test/15 & Post-test/15	26	.914	.000

Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error	95% Confidence Interval of the Difference				
				Lower	Upper			
Pair 1 Pre-test/15 - Post-test/15	-2.7692	1.2428	.2437	-3.2712	-2.2672	-11.361	25	.000

Grade 6 control male SSKT pre and post-test

Tests of Normality

	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Paired difference G6 control male	.213	25	.005	.920	25	.051

a. Lilliefors Significance Correction

Paired Samples Statistics

	Mean	N	Std. Deviation	Std. Error Mean
Pair 1 Pre-test/15	7.280	25	2.8507	.5701
Post-test/15	10.240	25	2.6026	.5205

Paired Samples Correlations

	N	Correlation	Sig.
Pair 1 Pre-test/15 & Post-test/15	25	.844	.000

Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
		Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pair 1 Pre-test/15 - Post-test/15	-2.9600	1.5406	.3081	-3.5959	-2.3241	-9.607	24	.000

Grade 6 Experimental female SSKT pre and post-test

Tests of Normality

		Kolmogorov-Smirnov ^a			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Paired difference G6 experimental female		.195	26	.012	.931	26	.083

a. Lilliefors Significance Correction

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pre-test/15	8.077	26	2.2965	.4504
	Post-test/15	13.077	26	1.6229	.3183

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Pre-test/15 & Post-test/15	26	.546	.004

Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error	95% Confidence Interval of the Difference				
				Lower	Upper			
Pair 1 Pre-test/15 - Post-test/15	-5.0000	1.9596	.3843	-5.7915	-4.2085	-13.010	25	.000

Grade 6 experimental male SSKT pre and post-test

Tests of Normality

	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Paired difference G6 experimental male	.280	25	.000	.875	25	.005

a. Lilliefors Significance Correction

Paired Samples Statistics

	Mean	N	Std. Deviation	Std. Error Mean
Pair 1 Pre-test/15	7.400	25	2.5820	.5164
Post-test/15	12.000	25	2.1794	.4359

Paired Samples Correlations

	N	Correlation	Sig.
Pair 1 Pre-test/15 & Post-test/15	25	.792	.000

Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error	95% Confidence Interval of the Difference				
				Lower	Upper			
Pair 1 Pre-test/15 - Post-test/15	-4.6000	1.5811	.3162	-5.2527	-3.9473	-14.546	24	.000

Grade 7 control female SSKT pre and post-test

Tests of Normality

	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Paired difference G7 control female	.155	27	.096	.929	27	.064

a. Lilliefors Significance Correction

Paired Samples Statistics

	Mean	N	Std. Deviation	Std. Error Mean
Pair 1 Pre-test/15	7.222	27	2.5621	.4931
Post-test/15	10.704	27	2.7709	.5333

Paired Samples Correlations

	N	Correlation	Sig.
Pair 1 Pre-test/15 & Post-test/15	27	.811	.000

Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error	95% Confidence Interval of the Difference				
				Lower	Upper			
Pair 1 Pre-test/15 Post-test/15	-3.4815	1.6495	.3174	-4.1340	-2.8290	-10.967	26	.000

Grade 7 control male SSKT pre and post-test

Tests of Normality

	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Paired difference G7 control male	.206	25	.007	.925	25	.068

a. Lilliefors Significance Correction

Paired Samples Statistics

	Mean	N	Std. Deviation	Std. Error Mean
Pair 1 Pre-test/15	6.560	25	2.5179	.5036
Post-test/15	10.800	25	2.0817	.4163

Paired Samples Correlations

	N	Correlation	Sig.
Pair 1 Pre-test/15 & Post-test/15	25	.261	.208

Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error	95% Confidence Interval of the Difference				
				Lower	Upper			
Pair 1 Pre-test/15 - Post-test/15	-4.2400	2.8178	.5636	-5.4031	-3.0769	-7.524	24	.000

Grade 7 experimental female SSKT pre and post-test

Tests of Normality

		Kolmogorov-Smirnov ^a			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Paired difference	G7	.181	25	.034	.933	25	.100
experimental female							

a. Lilliefors Significance Correction

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pre-test/15	7.200	25	2.0616	.4123
	Post-test/15	12.080	25	2.1000	.4200

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Pre-test/15 & Post-test/15	25	.516	.008

Paired Samples Test

		Paired Differences				t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference			
					Lower	Upper		
Pair 1	Pre-test/15 - Post-test/15	-4.8800	2.0478	.4096	-5.7253	-4.0347	-11.915	.000

Grade 7 experimental male SSKT pre and post-test

Tests of Normality

		Kolmogorov-Smirnov ^a			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Paired difference	G7	.246	25	.000	.842	25	.001
experimental male							

a. Lilliefors Significance Correction

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pre-test/15	6.880	25	2.5219	.5044
	Post-test/15	11.920	25	1.9562	.3912

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Pre-test/15 & Post-test/15	25	.572	.003

Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error	95% Confidence Interval of the Difference				
				Lower	Upper			
Pair 1 Pre-test/15 - Post-test/15	-5.0400	2.1307	.4261	-5.9195	-4.1605	-11.827	24	.000

Grade 8 control female SSKT pre and post-test

Tests of Normality						
	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Paired difference G8 control female	.195	25	.015	.902	25	.020

a. Lilliefors Significance Correction

Paired Samples Statistics				
	Mean	N	Std. Deviation	Std. Error Mean
Pair 1 Pre-test/15	7.200	25	2.4152	.4830
Post-test/15	9.840	25	2.8531	.5706

Paired Samples Correlations			
	N	Correlation	Sig.
Pair 1 Pre-test/15 & Post-test/15	25	.870	.000

Paired Samples Test								
	Paired Differences					t	df	Sig. (2-tailed)
		Std. Deviation	Std. Error	95% Confidence Interval of the Difference				
				Mean	Lower			
Pair 1 Pre-test/15 - Post-test/15	-2.6400	1.4107	.2821	-3.2223	-2.0577	-9.357	24	.000

Grade 8 control male SSKT pre and post-test

Tests of Normality						
	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Paired difference G8 control male	.135	25	.200*	.945	25	.189

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pre-test/15	3.200	25	1.4434	.2887
	Post-test/15	9.360	25	3.2772	.6554

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Pre-test/15 & Post-test/15	25	-.280	.175

Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error	95% Confidence Interval of the Difference				
				Lower	Upper			
Pair 1 Pre-test/15 - Post-test/15	-6.1600	3.9336	.7867	-7.7837	-4.5363	-7.830	24	.000

Grade 8 experimental female SSKT pre and post-test

Tests of Normality

		Kolmogorov-Smirnov ^a			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Paired difference	G8 experimental female	.242	25	.001	.905	25	.023

a. Lilliefors Significance Correction

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pre-test/15	7.040	25	2.5573	.5115
	Post-test/15	11.880	25	1.9218	.3844

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Pre-test/15 & Post-test/15	25	.501	.011

Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error	95% Confidence Interval of the Difference				
				Lower	Upper			
Pair 1 Pre-test/15 - Post-test/15	-4.8400	2.3036	.4607	-5.7909	-3.8891	-10.505	24	.000

Grade 8 experimental male SSKT pre and post-test

Tests of Normality

	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Paired difference G8 experimental male	.220	25	.003	.908	25	.028

a. Lilliefors Significance Correction

Paired Samples Statistics

	Mean	N	Std. Deviation	Std. Error Mean
Pair 1 Pre-test/15	3.320	25	1.2819	.2564
Post-test/15	12.040	25	2.6058	.5212

Paired Samples Correlations

	N	Correlation	Sig.
Pair 1 Pre-test/15 & Post-test/15	25	-.041	.844

Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error	95% Confidence Interval of the Difference				
				Lower	Upper			
Pair 1 Pre-test/15 Post-test/15	-8.7200	2.9513	.5903	-9.9382	-7.5018	-14.773	24	.000

Sample of Summary of Grade 8 Paired samples t-test data combination

Paired Samples Statistics

Group	Gender			Mean	N	Std. Deviation	Std. Error Mean
G8 Experimental	F	Pair 1	Pretest	7.040	25	2.5573	.5115
			Posttest	11.880	25	1.9218	.3844
	M	Pair 1	Pretest	3.3200	25	1.2819	.2564
			Posttest	12.0400	25	2.6058	.5212
G8 control	F	Pair 1	Pretest	7.200	25	2.4152	.4830
			Posttest	9.840	25	2.8531	.5706
	M	Pair 1	Pretest	3.200	25	1.4434	.2887
			Posttest	9.360	25	3.2772	.6554

Paired Samples Correlations						
Group	Gender			N	Correlation	Sig.
G8 Experimental	F	Pair 1	Pretest & Posttest	25	.501	.011
			Pretest & Posttest	25	-.041	.844
G8 control	F	Pair 1	Pretest & Posttest	25	.870	.000
			Pretest & Posttest	25	-.280	.064

Paired Samples Test											
Group				Paired Differences				t	df	Sig. (2-tailed)	
				Mean	Std. Deviation	Std. Error	95% Confidence Interval of the Difference				
							Lower				Upper
G8 Experimental	F	Pair 1	Pretest Posttest	-4.8400	2.3036	.4607	-5.7909	-3.8891	-10.505	24	.000
	M	Pair 1	Pretest Posttest	-8.7200	2.9513	.5903	-9.9382	-7.50178	-14.773	24	.000
G8 control	F	Pair 1	Pretest Posttest	-2.6400	1.4107	.2821	-3.2223	-2.0577	-9.357	24	.000
	M	Pair 1	Pretest Posttest	-6.1600	3.9336	.7867	-7.7837	-4.5363	-7.830	24	.000

Research Question 2

MAP Growth Normality Tests and P-P Plot Graphs

Tests of Normality

	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
MAP Growth G6 control	.136	49	.024	.948	49	.030
MAP Growth G6 experimental	.163	48	.003	.949	48	.035
MAP Growth G7 control	.211	51	.000	.925	51	.003
MAP Growth G7 experimental	.222	50	.000	.917	50	.002
MAP Growth G8 control	.218	49	.000	.900	49	.001
MAP Growth G8 experimental	.180	48	.000	.923	48	.004

a. Lilliefors Significance Correction

