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Impact of the Rigorous Curriculum Design for Project-Based Learning Implementation on Middle School Students' Science Achievement and MAP Progress

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Abstract

The innovative-based economies such as Finland and other developed countries, offer a viable cohesive, and sustainable curriculum centralized around Project-Based Learning (PBL) and built on the Rigorous Curriculum Design (RCD). Such curriculum is developed by schools and warrants examination in developing countries such as the United Arab Emirates to ensure contextual, cultural, and work-driven demands of second language learners and how it impacts students' achievements and high-stake testing. Thus, the main purpose of this study was to examine the impact of the rigorous curriculum design for project-based learning implementation on middle school students' science achievement and MAP progress in a private American school in Abu Dhabi, United Arab Emirates. The study followed a quantitative approach by collecting data using the Standardized Science Knowledge Test (SSKT) and the Measure of Academic Progress (MAP) in science for 304 middle school students from grades 6 to 8. Descriptive and inferential statistics were used to analyze the data. The results have shown that the RCD-PBL science units have a positive impact on teaching and learning and largely impact the students' achievements and improve their MAP progress and scores. All students in the experimental groups of grades 6, 7, and 8 showed improvement in the SSKT and outperformed their corresponding control groups. Participating middle-grade students on all levels who implemented the RCD-PBL demonstrated greater science academic growth, as indicated by both tools, the SSKT and the MAP, 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.

Keywords: rigorous curriculum design, project-based learning, Measure of Academic Progress, Science Curriculum

1. Introduction

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). While students show an early interest in science at a young age, this interest does not last throughout their education (Maltese, Melki, & Wiebke, 2014). Their experience with science in school is influenced by teachers' pedagogical approaches, and how science is delivered and assessed (Mantra, 2017). Following the lead of countries with innovative-based economies and educational approaches such as Finland (Finnish National Board of Education, 2016; Lederman et al., 2019) a viable cohesive, and sustainable curriculum centralized around project-based learning (PBL) is one of these approaches that is implemented. It focuses pedagogically on how rather than what, students are learning (Kramer et al., 2007). In addition, it allows students to be engaged 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 the final products all while using the knowledge and skills acquired (Aldabbus, 2018; Ardi, 2015).

Achieving an outstanding quality in education is one of the most important pillars of the United Arab Emirates (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 (Goh & Dimmock, 2011; Jamhari et al., 2018; Ponnusamy & Gopinathan, 2013). Unfortunately, the recent trend in the UAE tests has shown a downfall in students' achievement scores in benchmark and international tests specifically in science (Kamal & Trines, 2018; OECD, 2019; Schleicher, 2019) whereby the curriculum is heavily focused on the memorization of concepts rather than the construction of knowledge (Ridge et al., 2017), thus affecting the aspiration and the country's vision and plans.

Centralizing PBL in Science can only happen through a high-quality, comprehensive student-centered delivery system known as Rigorous Curriculum Design (RCD) as defined by Larry Ainsworth that serves as a roadmap for teachers whereby the alignment between the fundamental curriculum elements ensures student achievement and attainment of required grades standards within a grade level or subject. While Project-based learning has been established, recognized, and implemented in schools to various degrees for many years, particularly in North America, Europe, and some of Western Asia (Chen & Yong-Cih, 2019; Eckersall, 2017; Mahasneh & Alwan, 2018; Rubrica, 2018; Sahli, 2017), 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, increase knowledge retention; improve academic results; and enable them to be lifelong learners (Chen & Yong-Cih, 2019; Condliffe et al., 2016; Krajcik et al., 2021; Saavedra et al., 2021; Sahli, 2017), very few research has studied the effectiveness of PBL science curricula implementation on students' achievements in external assessment (Eckersall, 2017; Rubrica, 2018; Sahli, 2017; Yokom, 2020) especially Measure of Academic Progress (MAP) when developed by teachers as the basis of their whole curriculum, in the MENA region, especially in the UAE.

Diving into the literature, most of the PBL studies have shown that the implementation of PBL contributes to the development of knowledge, and intellectual skills, and the formation of students' attitudes (Handrianto & Rahman, 2018). In addition, examining the traditional classroom offered 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). Such hiding spaces are non-existent in a PBL-active classroom environment that is dominated by student-centered tasks. Thus, a traditional educational system that promotes a readymade educational level turned out to be a failure in comparison to PBL (Bas, 2011; Holthuis et al., 2018). Therefore, the curriculum should be authentic, primarily 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). This in turn embeds the three distinct dimensions of learning science advocated by the Next Generation Science Standards (NGSS): 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).

Furthermore, 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 a solution in case of any on-ground anomaly faced (Chen & Yong-Cih, 2019; Condliffe et al., 2016; Kwietniewski, 2017; Mahasneh & Alwan, 2018; Rubrica, 2018; Sahli, 2017; Thomas, 2000). While most of the studies were carried out in the United States, Western and East Asian countries, the results revealed that PBL has improved students' academic achievements (Kwietniewski, 2017) in addition to improving students' growth scores in MAP specifically in Math and Reading along with directing educators to fully implementing Common Core State Standards which allows students to gain a deeper understanding and knowledge of the concepts taught (Sahli, 2017). Moreover, two recent university studies, funded by Lucas Education Research have shown that learners in PBL advanced placement classrooms (Saavedra et al., 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. This was in line with the majority of the studies in this area, which demonstrated how PBL outperformed any pedagogical strategy, particularly traditional instructions (Krajcik et al., 2021; Saavedra et al., 2021; The National Academics of Sciences, 2019), for five main reasons. These include authentic and meaningful learning experiences (Darling-Hammond et al., 2019a) ensuring students' buy-in and engagement in a project (Yokom, 2020), presenting the outcome of the project to an audience allows students to embrace their skills, and expanding and transferring the application of knowledge beyond their classroom walls (The National Academics of Sciences, 2019). Lastly, working as a team in PBL teaches students how to embrace and respect each other's background experiences and perspectives, which helps create a culture of belonging (Darling-Hammond et al., 2019a). Finally, while most of the literature and reviews conducted on PBL emphasized its effectiveness in K-12 settings, very few studies were conducted in terms of the development and implementation of PBL curricula that impact students' science achievement and their MAP assessments globally and in particular the UAE. Therefore, the purpose of this study was to examine the impact of the rigorous curriculum design for PBL implementation on middle school students' science achievement and MAP scores in Abu Dhabi schools, UAE. Two main questions drive this study:

RQ1: To what extent does rigorous curriculum design for project-based learning implementation affect middle school students' science achievement in Abu Dhabi schools?

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

2. Theoretical Framework

This study has its roots in the constructivist learning theory whereby its 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 the NGSS framework constitute the main engine of the study and are shown in Figure 1.

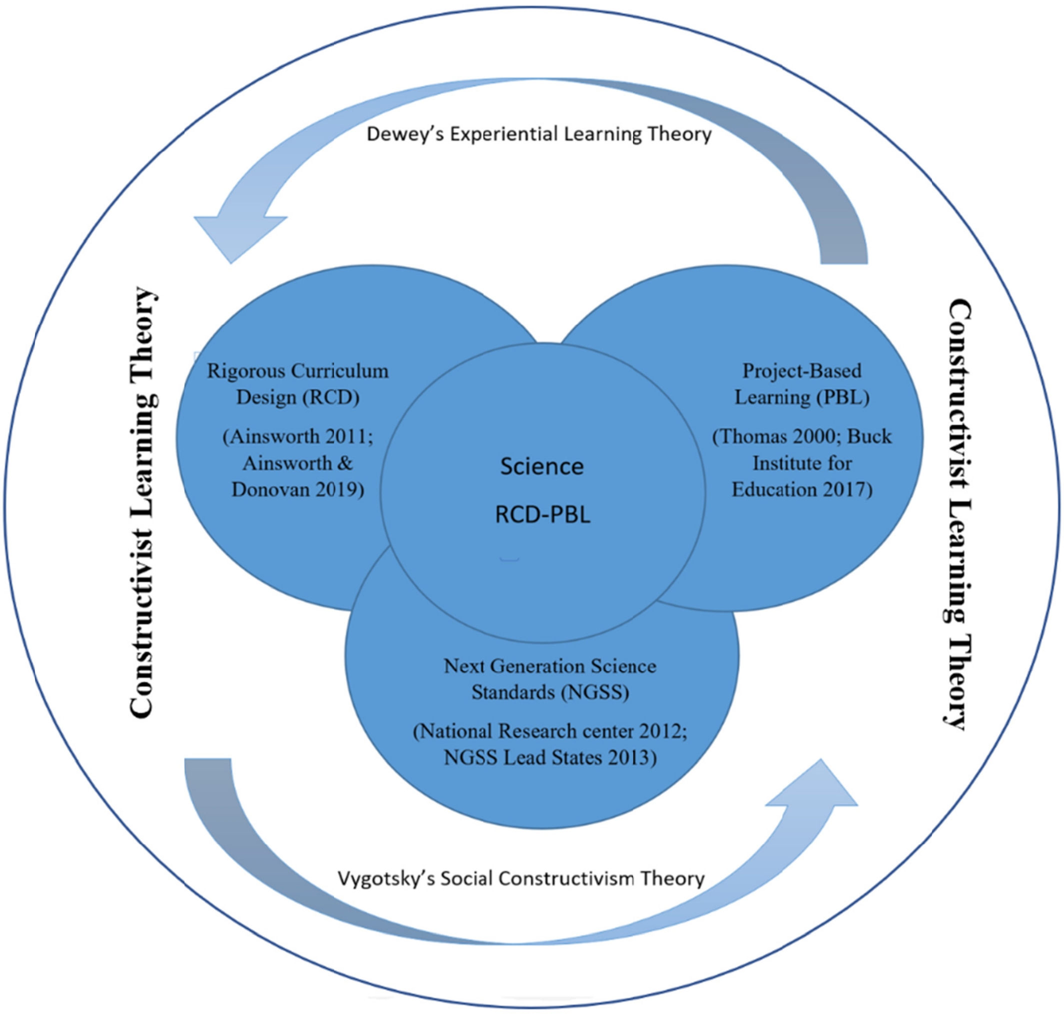

Figure 1. Theoretical framework of the study

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). 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 the construction of knowledge through learning outcomes as well as determining learning goals from authentic assessments (Von Glasersfeld, 1995). As constructivism is the idea that claims that learners build knowledge rather than merely passively comprehend information, its 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 for which it is used to grasp academic standards (Stenger, 2003).

2.1 Rigorous Curriculum Design

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). To ensure 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 provides 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.

According to Ainsworth (2019), the RCD 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' assessments 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 is 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 Buck Institute of Education Gold Standard Project-Based Learning Model

To capture the uniqueness of this approach, five criteria were stated by Thomas (2000): Curriculum core, driven questions, constructive investigation, autonomy, and realism. 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). Unlike problem-based learning which is a type of project-based learning, PBL requires constructing and delivering a product that addresses the project's main purpose (Condliffe et al., 2017; Savery, 2019). These projects are chosen based on students' interests and are driven by questions or problems that allow students to learn the central 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 by 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 (Buck Institute for Education, 2019a, 2019b; Rubrica, 2018). This guiding model encompasses seven essential project design elements that are based on students' learning goals of the reflection (key knowledge, understanding, and success skills) (Buck Institute for Education, 2019a; Larmer et al., 2015). These include challenging problems or questions, sustained inquiry, authenticity, student voice and choice, reflection, critique and revision, and public product. Challenging problem or question is the heart of any project, sustained inquiry is a rigorous inquiry cycle process, authenticity motivates students to learn, student voice and choice increase engagement, reflection helps students overcome obstacles, critique and revision help students adjust and improve their work processes, and public product helps increase the quality of the work submitted and create a learning community.

Referring to Larmer, Mergendoller, and Boss's (2015) description of the "Gold Standard PBL", a well-designed PBL curriculum should highlight the importance of concepts, content standards, and an in-depth understanding of school courses and disciplines. In addition, Krajcik and Shin (2014) emphasized the significance of developing such curricula around precise learning outcomes that are in line with national standards, particularly in science where the NGSS performance expectations are the learning performances that connect the core ideas to the key practices and crosscutting concepts (Marzano et al., 2016; NGSS Lead States, 2013). While RCD has engaging and authentic learning experiences as its core, its attributes are incorporated within the learning experiences (Ainsworth & Donovan, 2019; Eckersall, 2017; Sahli, 2017) and are aligned and overlap with the BIE Gold standard PBL model. Thus, the RCD will be a collection of PBL units based around meaningful and authentic GRASPS tasks whereby its crosswalk and alignment with the BIE PBL model is highlighted in Table 1. Finally, developing PBL units by adopting the RCD student-centered model for the middle school science curriculum is important as this cycle has been shown to have the highest impact on college and career readiness (Bender, 2019).

Table 1. 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 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 life 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

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 (Holthuis et al., 2018; Schwarz et al., 2017; Three-Dimensional Learning, 2020). Shifting toward 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). 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 its instructional strategies and assessment (NGSS Lead States, 2013). 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 also 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 and rubrics were developed and based on these standards.

3. Literature Review

3.1 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 et al., 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 (Krajcik et al., 2021; Saavedra et al., 2021; The National Academics of Sciences, 2019) 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 thorny issues, and iterate until they solve problems (Darling-Hammond et al., 2019b). Secondly, ensuring Students' buy-in and engagement in a project that addresses the standards and meets the learning outcomes depends on the topic chosen, interests, and needs (Yokom, 2020). 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 investigations, or presenting to an audience 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 et al., 2019a). 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.

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 its impact on students' outcomes specifically MAP, as limited research studies were conducted on these topics. 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. While all studies reviewed by Chen and Yong-Cih (2019) regarding PBL and students' academic achievement in primary, secondary, and tertiary education and the factors that influenced such approaches 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 on students' performance in different countries as well as to study the effect of PBL on teachers' and students' affective outcomes 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 accommodates the implementation of PBL as an instructional approach and assessment type. Furthermore, Sahli (2017) has shed light on the effectiveness of PBL instructions by 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 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. Similarly, Ergul and Kargin (2014) studied the effect of PBL on grade 6 students' success in electricity in life units in two elementary schools in Turkey. Their study revealed that PBL increased students' achievement when comparing pre-test and post-test results between experimental (PBL method) and control groups (Ministry of Education programme). 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 projects. 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 and 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.

3.2 PBL Implementation Challenges

Several factors interfere with the proper implementation of PBL in the learning process such as the student, the teacher, the parents, the curriculum, the assessment type, and the workshops. 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 using 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). Another major challenge to implementing PBL in high schools is related to instructional time 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 were taken into consideration and accounted for in this study.

3.3 Project-Based Learning Assessment

PBL has its roots in 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, or technology, and can guide students to reach completion of complex tasks (Darling-Hammond et al., 2008; Krajcik & Shin, 2014). According to the literature, there is a gap and disconnection between the type of learning that is based on PBL, the learning assessment, and teachers' accountability (Condliffe et al., 2016; Parker et al., 2013). A shift in education requires a reform in curriculum and a change in assessment type (Orpwood, 2001; Parker et al., 2013; Thomas, 2000). In addition, PBL requires suitable assessment practices to ensure that the learning process tackles all students. Embedding assessment throughout the project is based on three approaches (Condliffe et al., 2016): Ensuring that a project is delivered to an authentic audience (Lenz et al., 2015; Polman et al., 2014), addressing its goals based on the standards assessed and its driven questions (Krajcik & Shin, 2014) as well as 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 expectations are assessed through projects that integrate science, engineering practices, and technology (Sahin, 2019). Additionally, the basis of PBL is the development of projects (Yokom, 2020) whereby students are requested to apply, demonstrate, and reflect on their learning through performance-based assessment (Boss, 2012). Referring to Tal, Krajcik, and Blumenfeld's (2006) definition of PBL, students will be involved in authentic investigation driven by questions whereby students' engagement in this context increases 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. Therefore, adopting a performance-based assessment that produces an artifact at the end of the unit by tackling the standards assessed and has all components of a project as defined earlier by Thomas (2000) should increase students' academic achievement and ensure their readiness and success in personal life and career (Buck Institute, 2018). Moreover, adopting performance-based assessment, also known as project-based assessment in a project, problem, and inquiry-based curriculum is relevant as it is aligned with how students learn (Kabba, 2008). A research study by Hairida and Junanto (2018) research study has shown that applying performance-based assessment, particularly in PBL has helped students develop science literacy competencies. Looking over PBL research studies in literature, it has been found that projects increase students' interest (Fortus, Krajcikb, Dershimerb, Marx, & Mamlok-Naamand, 2005) and attitudes toward STEM careers as it involves collaboration and cooperation between students in producing artifacts by solving authentic real-life problems Berk et al. (2014). Thus, adopting authentic performance-based assessment (GRASPS) will challenge students to apply their knowledge and skills to solve real-world problems by creating a product (Barnes & Urbankowski, 2014).

3.4 Measure of Academic Progress 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 (Jones, 2015; NWEA, 2012). 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, the teachers, and the parents an insight into individual student's knowledge level and what future concepts and skills they will be ready to learn (Cordray et al., 2012).

Currently, education sectors and schools are interested in implementing benchmark exams, specifically NWEA MAP for their 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 (Jones, 2015; Medford, 2014; NWEA, 2012). 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).

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 of 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 approach on student achievement and growth. Finally, evaluating the effectiveness of RCD-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.

3.5 Teachers' Perceptions Towards Project-Based Learning

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 followed 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 believe 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). Through questionnaire, semi-structured interviews, and observation, Whitaker (2019) explored four middle school teachers' perceptions towards PBL's impact when implemented in the curriculum of a high-poverty school in South Carolina for its first year over a period of 10 weeks as a way to prepare students for state tests. The results have showed that even though teachers had positive perceptions of PBL, its implementation was hindered by technical challenges that 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 a 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; Viro et al., 2020; Whitaker, 2019) 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 et al., 2017; Whitaker, 2019). Furthermore, Habók and 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, Yalvac, et al., 2015). Overcoming PBL facilitation in a curriculum, teachers require experience, and a deeper understanding of the implementation approach (Mentzer et al., 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.

4. Methods

The study follows a quantitative approach through a post-positivistic paradigm which has basic characteristics, of "determination" where there is a cause for each outcome or effect and the focus on variables and relationships between them (Creswell, 2009) which was precisely what this study aimed to, examining the impact of the rigorous curriculum design (RCD) for PBL implementation on middle school students' science achievement and MAP scores in Abu Dhabi schools. The quantitative data is collected using the Science Standard Knowledge Test (SSKT), and the Measure of Academic Progress (MAP) scores through a quasi-experimental study. Therefore, the study adopted this approach as the quantitative data provides a generalized picture of the core study problem.

The site of this 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). The population of all grades in the school is about 4,000 students, most of whom are Emiratis, and with a very good Abu Dhabi Department of Education and Knowledge (ADEK) report. In addition, as one of the researchers 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 UAE 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 external assessment 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.

The study sample consisted of 25 middle school teachers who implemented the RCD-PBL model. They 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, non RCD-PBL, textbook method to be able to compare the two instructional modes of science delivery. In addition, the target population of middle school students was 955 from across grades 6 to 8. Each grade level is divided into sections/classes whereby each section 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 the RCD-PBL model, 304 participants from 12 science classrooms took part in this study. From these 12 science classrooms, 6 classes followed the RCD-PBL curriculum model (experimental group), while the 6 other classes adhered to the conventional textbook-based curriculum (non RCD-PBL) (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 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

Note. 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 is expected to be related to different skills and learners' achievement levels (Fraenkel et al., 2015). While the course goals, objectives, and outcomes may be the same for both traditional (non RCD-PBL) and project-based learning (RCD-PBL) classroom groups, Table 3 differentiates considerable variations in fundamental assumptions about teachers, knowledge, students, and learning.

Table 3. Differences between traditional instruction and PBL classrooms.

RCD-PBL Classroom "Experimental Groups"	**Non RCD-PBL "Control Groups"**
The curriculum emphasizes big concepts, beginning with the whole and expanding to include parts.	The 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.
The pursuit of students' questions, opinions, and interests is valued.	Strict adherence to the fixed curriculum.
Resources include primary sources of materials and simulations, hands-on practicals, and experiments.	Resources are mainly based on textbooks and 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 is 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.

Moreover, convenient sampling with specific selection criteria was adopted as it is 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, a similar mean and standard deviation deriving from their MAP scores Fall to Winter 2020–2021 were selected in each grade level. The link was shared with all teachers through the daily bulletin message sent by the administrator every morning with a clear purpose of targeting middle school teachers who were involved in the study to increase participation and honesty in response.

Two instruments were used, (1) the Science Standardized Knowledge Test (SSKT) developed to measure middle school students' achievement the SSKT was written by 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 the end of the first unit of implementation. The tests were piloted and shared with 10 students from each grade level to grasp their feedback in terms of language, clarity, format, and the average time to answer these test questions. A quasi-experiment pretest-posttest non-equivalent control group design method was used whereby the RCD-PBL was implemented as the treatment for the experimental group while no treatment was implemented in the control group that was still adopting the traditional approach (textbook). The pre- and post-SSKT were administered and shared with all students at the same time on teams through an MS Form link. This SSKT Pre-Post test was checked against content-related validity to ensure the appropriateness of the content and logical structure of the instrument. In addition, 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). Furthermore, Cronbach's alpha coefficient was calculated 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 4. The SSKT pre-posttest results were generated from forms onto an Excel sheet and then embedded in Statistical Package for Social Sciences (SPSS) for analysis.

Table 4. Reliability pilot test result of SSKT

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

(2) The Measure of Academic Progress (MAP) 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 who 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. Although the MAP test is typically untimed, one block of 90 minutes is allocated to perform the test. MAP testing was done twice per year in the Fall and in the Spring. The scores from both administrations 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. After completing the MAP test, students' data results are collected electronically, and the Achievement Status Growth projection report (ASG) was generated through the NWEA server, however, only students with valid MAP growth scores data were selected. The students' projected growth results generated from the ASG reports 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 (The same 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) indicates that the student gained a low score in Spring compared to his/her score in Fall administration.

To answer the two research questions, descriptive statistics such as mean, standard deviation as well as inferential statistics were computed using SPSS-23. Descriptive statistics are considered the groundwork of this type of data whereby it is used to summarize, describe, and make sense of a 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. The sections below present data analysis and results.

5. Results

5.1 Results of Student's Science Achievement in SSKT

To study the effect of RCD-PBL on students' science achievement in SSKT the researcher intended to find firstly, if there is a statistically significant difference in terms of students' academic achievement means in science between experimental and control group pre-posttest scores (Paired sample t-test). Secondly, 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). Finally, if there is 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). An effect size was calculated for both paired and independent sample t-tests 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). Furthermore, Fisher's least significance difference (LSD) and Tukey's honestly significant difference (HSD) were the post hoc tests 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.

In order to determine if there is a statistically significant difference between Pre-Posttest SSKT scores in science, a paired samples t-test was performed, and a summary of the results was represented in Table 5 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 grades 6,7, and 8. All students in the experimental groups of grades 6, 7, and 8 showed improvement in the SSKT and outperformed their corresponding control groups. Finally, the results have indicated that an average student in grades 6, 7, and 8 in the experimental group gained respectively 4.8039, 4.9600, and 6.780 points on the SSKT compared to a student in the control group who gained respectively an average of 2.8627, 3.8462, and 4.400 points.

Table 5. Summary of paired samples T-Test in SSKT scores in science for grades 6, 7, and 8

Grade Level	Pre-test		Post-test		Mean paired Difference	SD	t	df	Sig.	Effect size
	Mean	SD	Mean	SD						
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 results showed that 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. Moreover, a non-PBL male student on average gained more than the respective non-PBL female student for grades 6, 7, and 8 in the pre-test to post-test SSKT scores. Furthermore, 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 6 showed 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% (Saul, 2019) of the control group of students that did not receive the RCD-PBL (Saul, 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 6. Summary of mean students' improvement in SSKT scores

	Non-PBL		**PBL**						
Grade Level	**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

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 showed 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 females in grade 6 (M = 5.00, SD = 1.960) and experimental males respectively in grade 7 (M = 5.04, SD = 2.131) and grade 8 (M = 8.72, SD = 2.951). Analysis results in Table 7 showed statistically 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 7. 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)

As there is a statistically significant 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 8 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 males led to higher SSKT mean improvement in comparison with experimental females 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 8. The 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	
						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 9.

Table 9. 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	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

5.2 Results of Middle School Students' Science MAP Growth

To investigate 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 RCD-PBL). Levene's F test for equality of variances and Cohen's d test for independent sample t-test were also carried out. The Descriptive analysis of the MAP projected growth achievement represented in Figure 2 showed that Fifty-eight percent 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. In addition, sixty-three percent 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. It is worth noting that while 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%).

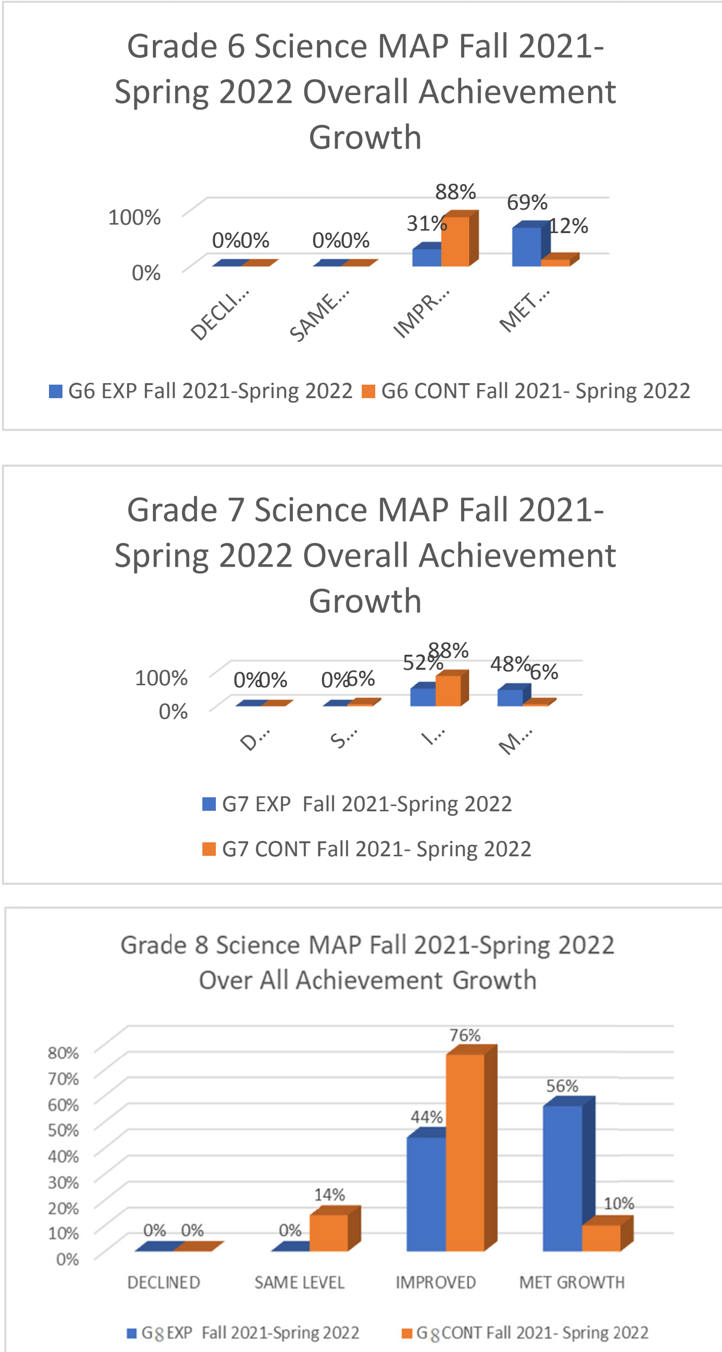

Figure 2. Middle school science grades 6–8 MAP fall 2021–spring 2022 overall achievement growth

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 (Table 10). 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 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.

Table 10. Independent T-Test for grades 6, 7, and 8 combined MAP growth scores

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

6. Discussion

To address the aim and research questions, the study involved quantitative analysis of data. The data comprised the grades 6, 7, and 8 pre-test and post-test SSKT scores along with Fall 21-Spring 22 MAP progress scores for middle school students from private schools in Abu Dhabi, UAE. The results of each research question are addressed below:

RQ1: To what extent does rigorous curriculum design for project-based learning implementation affect middle school students' science achievement in Abu Dhabi schools?

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 (Ergul & Kargin, 2014; Khaliq et al., 2015; Yalçın et al., 2009). Also, 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 other studies that investigated the effect of PBL on science achievement and observed no impact on students' outcomes (Araz & Sungur, 2007; Ayan, 2012; Kizkapan & Bektas, 2017; Yalçın et al., 2009). 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 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, 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; Chen & Yong-Cih, 2019; Karaçalli & Korur, 2014; Kizkapan & Bektas, 2017; Krajcik & Czerniak, 2018; Redmond, 2014; Sahli, 2017) 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 the experimental female group 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 correlation between RCD-PBL and its 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 male 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 (Jia et al., 2020; Makarova et al., 2019). 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; Ainsworth & Donovan, 2019; Holthuis et al., 2018; NGSS Lead States, 2013). 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 (Buck Institute for Education, 2019a; Holthuis et al., 2018). 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 (Chen & Yong-Cih, 2019; Kizkapan & Bektas, 2017; Krajcik et al., 2021; Kwietniewski, 2017; Liu et al., 2021; Saavedra et al., 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 (Aldabbus, 2018; Kwietniewski, 2017; 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 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.

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

Rigorous curriculum design for project-based learning implementation affects middle school science students (grades 6, 7, and 8) MAP growth scores for Fall 202l-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 RCD-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 also perceived and communicated by all the six interviewees who participated in this study.

Furthermore, the improvement in the science students' MAP growth scores has been observed across all grade levels 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 which 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. While all students taught using the RCD-PBL either improved or met the projected growth, of their peers in non-PBL 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 in comparison to their peers taught using the textbook curriculum from Fall 2021 to 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 only in the student's Zone of Proximal Development (ZPD) with the assistance of teachers inside the classroom (Vygotsky, 1962). If teachers can assist students in learning and take the role of a facilitator in PBL curricula, students will learn more easily within the ZPD, proving Vygotsky's point about the importance of assistance to learn new ideas and concepts by reflecting on their previous experiences. Moreover, 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 females are usually more worried and stressed in the exams (Akinsola & Fisayo, 2014; Jia et al., 2020; Lupinski & Jenkins, 2014; Saygin, 2018). 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 males 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.

Finally, such an increase in students' average MAP growth scores is due to teachers' involvement in planning, developing, and implementing such curricula as advocated by several research studies (Holm, 2011; Redmond, 2014; Alsubaie, 2016; Capraro et al., 2016; Kizkapan & Bektas, 2017; Ainsworth & Donovan, 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; Holm, 2011; Kingston, 2018; Thomas, 2000; Vygotsky, 1978). It is worth mentioning that students' MAP growth scores could be enhanced with time especially since this is the first year of implementation whereby teachers and students are getting used to such a curriculum (Kizkapan & Bektas, 2017). Also, some other factors could contribute to students' achievement (environment, parents' involvement, and support, resources, teacher-student relationship, etc.). Furthermore, the amount of time it requires to effectively implement and introduce the PBL tasks and build 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).

7. Conclusions and 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 shown that the RCD-PBL curriculum improves middle school science students' MAP scores and allows more students to meet or exceed their projected growth to meet the international norms. 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. In addition, grasping parents' and students' perceptions is required for the next stage since their involvement, and support, along with their opinions and recommendations provide valuable feedback that should be considered in the reflection process to enhance the assessment, instructions, and delivery of these types of units which should lead to better students' results. Moreover, grasping teachers' perceptions along with evaluating their qualifications, motivation, readiness, and willingness could be fundamental to increasing students' achievements as teachers are key mediators between standards and outcomes. 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. In addition to supporting the UAE educational reform, which aims to improve the quality of education in the UAE and pave the way to achieving its 2071 National Agenda.

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