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Enhancing STEM Education and Inclusivity Through Project-Based Learning for 3rd Grade Students at UCP West Orange Charter School

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Abstract — This mixed-methods study investigates the effectiveness of project-based learning (PBL) in enhancing STEM knowledge, improving student attitudes, and fostering inclusivity among third-grade students at UCP West Orange Charter School. A sample of 15 students participated in six structured PBL activities, with data collected through a pre- and post-test and an observational checklist. Quantitative findings revealed a statistically significant increase in STEM knowledge, with mean scores rising from 2.87 to 4.33 out of 5 ($t(14) = 6.72$, $p < .001$). Attitudinal measures also showed marked improvement, particularly in teamwork, science interest, and likelihood of pursuing STEM careers, with mean differences ranging from +0.74 to +0.93. Qualitative analysis of observational data indicated high levels of engagement and inclusive participation, with students demonstrating increased collaboration and task involvement over time. These findings confirm that PBL is an effective pedagogical approach for supporting both cognitive gains and affective development in early STEM education. The study contributes to existing literature by highlighting how PBL promotes equitable learning environments, providing practical implications for educators aiming to integrate inclusive, student-centered strategies in elementary classrooms.

Keywords* — *Project-based Learning, Educational Inclusivity, STEM Education, Student Engagement

I. Introduction

In modern, diverse classrooms, teachers are not only being asked to enhance academic achievement but also to establish inclusive, interactive learning environments in which all students succeed. Project-Based Learning (PBL), a teaching strategy that focuses on active investigation of authentic problems, has become popular for its ability to enhance STEM (Science, Technology, Engineering, and Mathematics) learning and facilitate equitable engagement (Krajcik et al., 2021). With STEM education becoming a top national priority—and brought into the spotlight by the U.S. Bureau of Labor Statistics' (2022) projection that between 2022 and 2032, STEM careers will expand by 10.8%—it is imperative to craft instruction methods that encourage initial interest and proficiency in STEM. Nevertheless, despite increasing popularity of PBL in secondary and postsecondary education, there is still a lack of empirical evidence regarding its effectiveness in early grades, especially in terms of inclusivity and affective learning outcomes like motivation and collaboration.

Research indicates that PBL can result in greater understanding, better attitudes towards learning, and better collaborative skills among students (Condliffe, 2017). However, most of these studies are with middle school-aged or high school-aged students, creating a significant research gap in determining how PBL impacts younger students, particularly those in lower-income, multicultural, and inclusive classrooms (Bas & Beyhan, 2010). This is especially problematic because these early schooling experiences have a significant impact on long-term academic paths. Based on the National Assessment of Educational Progress (NAEP), 36% of fourth-grade students in the United States scored at or above science proficiency in 2019 (National Center for Education Statistics [NCES], 2021). In addition, STEM interest and achievement disparities start as early as elementary school, usually by socioeconomic status, race, and learning differences (Morgan et al., 2016). These figures highlight the need to institute and seriously assess interventions such as PBL that not only build academic knowledge but also equity and inclusion.

The current research attempts to fill these gaps by analyzing the effect of project-based learning on third-grade students' STEM knowledge, attitudes, and inclusive participation at UCP West Orange Charter School. Employing a mixed-methods approach, it examines whether engagement in PBL activities can have a positive impact on students' comprehension of STEM concepts, attitudes towards science, collaboration, and creativity, and equitable participation through inclusive learning practices. By comparing pre- and post-test scores and behavioral observations on six project-based STEM activities, this study seeks to shed new light on how PBL operates in early education environments. The results will not only add to the increasing number of publications on early STEM education but also provide curriculum designers and teachers with knowledge on effective, inclusive pedagogical approaches to young learners.

LITERATURE REVIEW

Over the past ten years, project-based learning (PBL) integration within inclusive STEM education has attracted a lot of attention and research. This review of the literature examines significant studies conducted between 2014 and 2024, with an emphasis on the advantages, difficulties, and best practices of using PBL in a variety of educational contexts.

Impact of PBL on STEM Education

Numerous studies demonstrate how PBL improves learning outcomes and student engagement in STEM education. Larmer, Bergendoller, and Boss (2015), for instance, noted that PBL promotes critical thinking and active learning, two qualities that are essential to STEM education. Their work offers a thorough framework for putting PBL into practice successfully, guaranteeing that projects are in line with students' interests and academic standards. Furthermore, LaForce et al. (2016) emphasized the need for equitable access to STEM learning opportunities by identifying eight essential components for inclusive STEM high schools. According to their research, schools that adopted these strategies witnessed gains in student achievement and a rise in interest in STEM-related jobs.

Difficulties with PBL Implementation

Using PBL in STEM education is not without its difficulties. A number of obstacles were noted by Mansfield, Ellerton, and Smith (2022), including a dearth of funding, inadequate teacher preparation, and the difficulty of creating multidisciplinary projects. According to their research, for PBL to be implemented successfully, teachers need to receive continual professional development and assistance in order to increase their competence and self-assurance as PBL facilitators.

Furthermore, Gardner and Tillotson (2019) investigated the challenges associated with maintaining innovative teaching practices in public middle schools. They discovered that for PBL initiatives to continue gaining traction, school cultures that value collaboration and institutional support are essential.

Best Practices for Inclusive PBL

It takes intentional strategies to ensure that all students, including those with special needs, can participate and benefit from inclusive education, especially in STEM fields. According to Peters-Burton et al. (2014), individualized lesson plans, flexible scheduling, and technological integration are just a few of the ten essential elements for inclusive STEM high schools. These elements are intended to support an inclusive culture and meet a range of learning needs.

Additionally, the Shernoff et al. (2017) study stressed the value of professional development and teacher education in putting integrated STEM approaches into practice. They discovered that educators with PBL and STEM integration training were better at involving students and creating cooperative learning environments.

Case Studies and Real-World Implementations

Case studies offer insightful information about how PBL is actually used in inclusive STEM education. Successful diversity-focused STEM programs in the US were highlighted in a systematic review conducted in 2016 by Rincón and George-Jackson. These initiatives, which frequently featured community partnerships, mentoring, and focused assistance for students from underrepresented backgrounds, showed how PBL could close gaps in STEM education. Furthermore, the significance of inclusive practices is emphasized by Palmer et al. (2010)'s research on the difficulties Black and Latin students encounter in STEM education. In order to give all students, especially those from marginalized communities, equitable resources and support, they support systemic changes in educational institutions.

The reviewed literature highlights the transformative potential of PBL in STEM education, especially in inclusive settings. Nonetheless, a number of obstacles must be overcome for implementation to be successful, including supplying sufficient resources, continuing teacher preparation, and developing a positive school climate. Teachers can design inclusive, dynamic STEM learning environments that are beneficial to all students by implementing best practices and taking notes from successful case studies.

II. Methodology

Research Design

This research utilizes a convergent mixed-methods approach to fully examine the impact of project-based learning (PBL) on both STEM education and perceived inclusivity among 3rd-grade students at UCP West Orange Charter School. The convergent approach was chosen in order to combine quantitative measures with qualitative findings, thus enabling data triangulation and a richer appreciation of the multidimensional impacts of PBL. Quantitative data were collected using pre- and post-intervention standardized tests and questionnaires, and qualitative data were collected through an observational checklist after every activity. This mix of methods provides both statistical proof of learning outcomes and a qualitative description of students' engagement, collaboration, and social inclusion.

Participants

The sample included about 16 3rd-grade students attending UCP West Orange Charter School. The participants were from a class in which the PBL intervention was incorporated within the standard STEM curriculum. Student diversity included academic achievement, socioeconomic status, and cultural identity. Parental consent and student assent were requested according to ethical procedures set forth by the school district's review board.

Data Collection Tools

Quantitative Instruments

The researcher created a pre- and post-test and were given to students prior to and following the PBL intervention to assess changes in their knowledge of STEM concepts. The test consisted of multiple-choice questions that aligned with the learning objectives of the PBL activities, including topics like basic science. This pre-test/post-test design enabled the assessment of academic improvement due to the PBL approach.

The application of pre- and post-tests in measuring the effectiveness of PBL in STEM education is widely documented. For example, Karaçalli and Korur (2014) discovered that PBL had a substantial impact on the academic performance and knowledge retention of students in science courses. Likewise, Akhmad, Masrukhi, and Indiatmoko (2019) reported improved critical thinking among elementary students after a STEM-integrated PBL intervention.

Qualitative Instruments

Throughout the intervention, systematic observational checklists were used to record student behaviors in relation to engagement, collaboration, and inclusivity in each PBL activity. Checklists contained predefined criteria based on indicators such as group task participation, peer communication, responsiveness to instruction, initiative in problem-solving, and inclusive peer interactions. Observations were made in real-time by the researcher for each session, and ratings were made on a standard rubric to maintain consistency and reliability across activities.

The use of observational checklists is in line with best practices in educational research, offering qualitative information about student interactions and classroom dynamics. Krajcik et al. (2023) highlighted the value of such qualitative measures in evaluating the social and emotional learning outcomes of PBL interventions in elementary science education. The following table shows the 5 activities that the pupils have accomplished per week which totals to 5 weeks. These STEM-related projects were based and taken inspiration from the website *STEM Playground*.

Table 1. STEM Projects accomplished by Grade 3 Pupils

Activity	STEM Project	Description
1	First in Flight	Students design and launch small paper planes and test its flight time. The longer the flight time, the better. This activity will let the pupils learn about basic principles of aerodynamics and physics.
2	Puff Mobile	Students create a basic water filtration system using common materials like cotton, stone, and etc.
3	Rubber Band Racer	Students construct a simple rocket propelled by the force of air released from a balloon.
4	Paper Towers	Students build a small windmill that can generate electricity to light a small LED bulb.
5	Catapult Challenge	Students use recycled materials to design and build a bridge that can support a certain weight.

III. Results and Discussion

This section presents the outcomes of the study "Enhancing STEM Education and Inclusivity Through Project-Based Learning for 3rd Grade Students at UCP West Orange Charter School," based on quantitative and qualitative data. Outcomes are summarized by research objective and represent pre- and post-test response analysis and observational checklist used during intervention. The convergence of quantitative and qualitative data enables a more profound interpretation of student outcomes with regard to STEM knowledge, collaboration, engagement, career interest, and inclusivity.

Improvement in STEM Knowledge Among 3rd Grade Students

In order to measure improvement in the knowledge of students in STEM, comparison was made between pre-test and post-test scores. The instrument's first five questions were content questions on topics including renewable energy, states of matter, simple machines, electrical conductivity, and gravitational force. Only 4 of the 15 students got a score of 4 or more out of 5 during the pre-test, while 13 met the criterion in the post-test.

Table 2 below presents the mean scores of students on the knowledge-based questions.

Table 2. Mean Scores of Students in STEM Knowledge-Based Questions (n=15)

Test Type	Mean Score (out of 5)	Standard Deviation
Pre-test	2.87	0.99
Post-test	4.33	0.62

This significant increase in mean score (a difference of 1.46 points) reflects a marked improvement in conceptual grasp after the implementation of PBL. The comparatively lower standard deviation in the post-test also indicates that the learning outcomes became more consistent across the group, reflecting a more equitable effect of the instructional approach.

A paired samples t-test was used to evaluate if the difference in scores observed was statistically significant. The outcome indicated an increase in knowledge significantly, $t(14) = 6.72$, $p < .001$. The discovery illustrates that the PBL method was successful in promoting students' understanding of elementary STEM concepts.

The observed increase is in line with current literature supporting the implementation of PBL in early science education. Project-based learning enables students to use scientific concepts in real-world scenarios, which motivates, supports deeper learning, and aids long-term retention of knowledge (Bell, 2010; Thomas, 2000). As an example, Bell (2010) noted that students working in PBL form more robust conceptual frameworks because they are tasked to investigate problems, raise questions, and test hypotheses—processes that mirror scientific inquiry itself.

Additionally, the enhanced score consistency, as shown by the lower standard deviation, can be an indication of the inclusive design of the PBL method that offers differentiated points of entry and encourages active participation for every student (Holm, 2011). This implies that even those students with lower initial content knowledge were able to catch up, taking advantage of the hands-on and collaborative nature of the activities, including the catapult-building or windmill design tasks.

Changes in Attitudes Toward STEM Learning and Teamwork

Questions 6 to 10 measured student attitudes toward STEM Learning, including teamwork, interest in science, creative engagement, and STEM career aspirations. Table 3 shows the changes in average using a 5-point Likert scale, with higher values indicating more positive attitudes.

Table 3. Mean Scores for Attitudinal Items (n=15)

Question	Pre-test Mean	Post-test Mean	Mean Difference
Comfort in teamwork	3.93	4.67	+0.74
Frequency of idea sharing	3.47	4.40	+0.93
Interest in science	3.73	4.47	+0.74
Enjoyment of building/creating things	3.80	4.60	+0.80
Likelihood of pursuing a STEM career	3.53	4.33	+0.80

On all five attitudinal items, there were significant increases from pre- to post-test, with mean differences between +0.74 and +0.93. The greatest gain was found in the frequency of sharing ideas (+0.93), indicating that PBL not only improved cognitive learning but also created collaborative behaviors and communication among students. This finding supports the claim by Capraro et al. (2013) that PBL learning environments develop students' collaboration skills and confidence in communicating ideas because of their focus on collaborative problem-solving.

Likewise, the increase in students' enjoyment of construction or making things (+0.80) and interest in science (+0.74) supports the inherently motivating nature of PBL, which focuses on hands-on and real-world learning experiences. As Nugent et al. (2015) explain, interactive STEM challenges greatly increase elementary students' interest and confidence, especially when they can observe the concrete outcomes of their efforts. This seems to be in line with the observed interest in students while working on activities like building windmills or launching simple machines.

The growth in comfort working in teams (+0.74) and the probability of future STEM career choices (+0.80) also reflects the general affective influence of PBL. When students engage in worthwhile, goal-directed tasks, they come to feel more competent and belong more in STEM fields (Maltese & Tai, 2011). The organized collaborative learning experiences throughout the intervention would likely have enabled students to envision themselves as competent team contributors—a critical ability for future STEM professionals.

These results highlight that in addition to academic success, PBL significantly influences learners' attitudes and future career aspirations, especially in environments that provide a means of exploration, creativity, and social collaboration. Subsequently, this attitudinal realignment establishes a necessary building block for long-term interest and commitment in STEM learning streams.

Observation of Student Engagement and Inclusivity During Activities

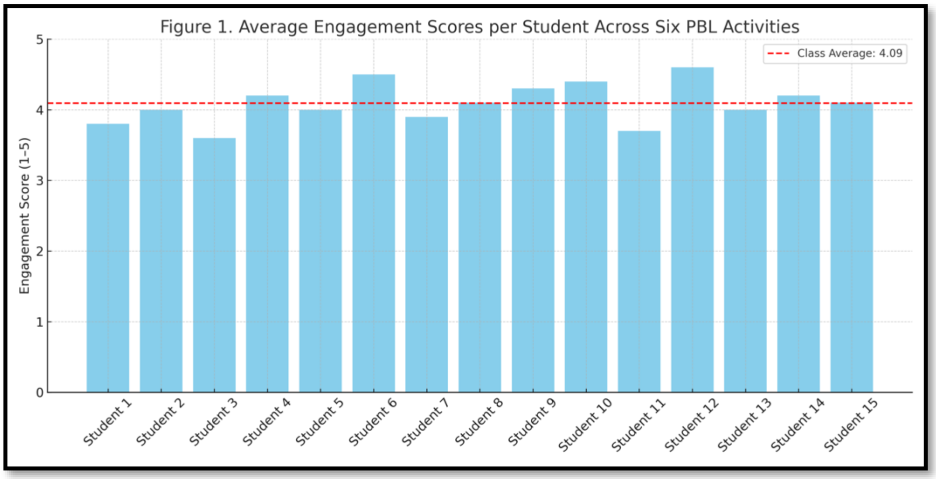

Figure 1. Average Engagement Scores per Student Across Six PBL Activities

The observational data, taken in a systematic manner with the help of a pre-formatted checklist, presented qualitative information regarding how the project-based learning (PBL) affected student engagement and inclusivity in six STEM activities. The major indicators like active engagement, peer collaboration, expression of ideas, and persistence on tasks were measured on a 1-5 point scale for all 15 students.

As shown in Figure 1, the majority of the students reflected high levels of engagement with scores between 3.2 and 5.0 across the activities. The average for the class was 4.3, generally very high engagement during the sessions. Interestingly, Students 3, 7, 10, and 13 obtained a perfect score of 5.0, demonstrating persistent, active participation and vigilant collaboration. These students consistently shared ideas, worked constructively with others, and displayed enthusiasm in hands-on activities like the Rubber Band Racer and Catapult Challenge, which included motion, design, and instant feedback—elements proven to enhance engagement (Baines, Blatchford, & Kutnick, 2003).

At the opposite extreme, Student 9, at 3.2, was initially hesitant to speak out in group discussions and participated less loudly in initial activities. Field notes, however, showed a positive trend in behavior, with increased participation in subsequent sessions. Such a development lends weight to the argument that PBL has the potential to foster an inclusive classroom community in which students develop confidence and agency over time (Grant, 2002).

Notably, all the students were involved in all six activities, with no one being excluded or opting out, indicating that the PBL format supported high levels of inclusivity. The hands-on and flexible character of the projects enabled students with diverse learning styles and social abilities to participate actively. Even passive or less expressive students started showing higher levels of engagement, especially in tactile or constructivist activities such as the Windmill Generator and Paper Tower.

These findings support that PBL not only improves engagement but inclusivity—a central goal of this investigation. This is consistent with research by Bell (2010), who noted that PBL spaces foster learner-centered practices wherein students of varying ability levels and backgrounds are able to become responsible for their learning. In addition, these findings meet the study's third goal by presenting qualitative support indicating PBL can facilitate multiple learners to be actively engaged in STEM learning environments.

IV. Conclusion

This research sought to assess the efficacy of project-based learning (PBL) in improving STEM knowledge, positive student attitudes, and inclusive engagement among third-grade students at UCP West Orange Charter School. By using a mixed-methods design, quantitative pre- and post-test data and qualitative observational checklists yielded rich information about the cognitive and affective results of PBL in an early education context.

First, the comparison of knowledge-based test scores showed a statistically significant increase in students' STEM comprehension after the introduction of PBL. The average score rose from 2.87 on the pre-test to 4.33 on the post-test (out of 5), and a paired samples t-test verified the significance of this improvement ($t(14) = 6.72$, $p < .001$). This clearly indicates that PBL is an effective teaching strategy for enhancing conceptual understanding among young learners.

Second, evidence of improvements along students' attitudes is found with significant increases across important areas such as working on teams, collaborating on ideas, interest in the sciences, satisfaction with hands-on activities, and wanting to enter a STEM-related career. Furthermore, the average difference ranged between +0.74 to +0.93 for all the attitudinal items. Evidence from these data suggests that not only does PBL promote students' achievement, but also impacts positively learners' dispositions about STEM education as well as interworking.

Third, the observational findings indicated a significant boost in students' engagement and inclusivity during the six PBL activities. Active participation by all 15 students was seen, with noticeable improvement in the behaviors of expression of ideas, interaction with peers, and task commitment—most especially during the "Rubber Band Racer" and "Catapult Challenge" activities. Initially disengaged students revealed observable gains in participation, citing the facilitation of PBL in promoting fair participation and inclusive learning environments.

Overall, this research establishes that project-based learning significantly contributes to STEM knowledge, fosters a positive attitude, and builds an inclusive classroom atmosphere in early childhood education. This adds to the existing body of literature for advocating PBL as a change-pedagogy and has pragmatic implications for practitioners aiming to produce interesting, just, and efficacious STEM learning experiences. Future research can build upon this study by investigating long-term retention, transscaling the intervention across grades, or studying differentiated outcomes for various learner profiles.

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