

Effect of Universal Design for Learning (UDL) Embedded Project on 5th Grade Students' Academic Achievement in Science Subject

Hira Javed*, Muhammad Athar Hussain** and Mubeshera Tufail***

Abstract

Traditional teaching practices lack student-focused learning, critical thinking, interactivity, creativity and student's engagement in the classroom, which results in boredom and low motivation among students. Moreover, these practices disregard diversification or variability in learners in a classroom. To engage such learners and create better conceptual understanding and interest in the subject, a research study was conducted in which inclusive Universal Design for Learning (UDL) framework infused Project Based Learning (PBL) approach was used. The study was conducted on the students of grade 5 of NUST Creative Learning School (NCLS) Pakistan. On experimental group (grade 5 class), self-made questionnaires (MCQs based) both in pre and post-test was conducted for General Science subject. A quantitative case study was conducted for an in-depth investigation of the case and to understand the process and its effects on students' learning. Data collection tools were predominantly quantitative tools with some qualitative aspects. This study proposed an idea for designing of evidence-based solutions to substitute the traditional teaching methods with UDL infused project-based learning lesson designs. Findings suggest that UDL complained PBL is an effective approach and framework to design adaptable and accessible learning content through research-based testing. It also recommends that such flexible lessons can approach a wide mix of different learner needs, abilities, prior knowledge, and learning styles to increase learning effectiveness and connect learner Knowledge to the real-world application.

Keywords: Focused Learning, critical thinking, UDL framework, Project-based learning.

*SEECs, NUST, Pakistan

**Associate Professor, ECE&ETE Department, Allama Iqbal Open University, Islamabad.
Email: muhammad.athar@aiou.edu.pk

***Lecturer, ECE&ETE Department, Allama Iqbal Open University, Islamabad

Introduction

Educational literature evidence that general education classrooms have been getting more diverse with time. Learning styles and differences can be observed in all students of a classroom. Students face difficulty in learning through a rigid and inflexible lesson and instructions being delivered in a classroom. They face the challenges of the persistence of ideas, retention of concepts, and lack of engagement and become unable to communicate their understandings (Al-Hazmi & Ahmad, 2018).

Universal Design for Learning (UDL) is a framework that attempts to tackle the limitations of a diverse learning classroom (Al-Azawei, Serenelli & Lundqvist, 2016). The origin of the term ‘Universal Design for Learning’ is attributed to David Rose, Anne Meyer and colleagues at Center for Applied Special Technology (CAST) (Edyburn, 2005) with Ronald L. Mace (1941-1998) considered as the father of the movement (Frolli, Cerciello, Esposito & Sica, 2022). Universal design aims to remove barriers and, to make products and environments accessible for all learners. It assumes every student as a unique being. It derives its base from Howard Garners’ theory of multiple intelligences and the research work in the field of neuroscience which takes into account the unique cognitive abilities and learning style (Barazza, 2023). UDL emphasizes to design curriculum in such a way that it can serve the learners irrespective of their age, gender, ability, competences, and socio-cultural and linguistic background. UDL framework is based on following three principles: multiple means of presenting the information, multiple ways for students to exhibit their learning, and multiple means for engaging students through variety of formats for presentation and adjustable levels of challenges (TEAL center staff, 2010).

Project-based learning enhances the learning skills of students and makes it self-directed, inquiry based, collaborative and interdisciplinary (Blumenfeld, Soloway, Marx, Krajcik, Guzdial & Palincsar, 2011). If UDL approach applies in compliances with Project-based learning, it can increase the learning outcomes of students in project-based learning (Capp, 2017). It is important for implementing Universal Design for Learning (UDL) that the teacher has a basic understanding of the UDL framework, a commitment to designing curricula in accordance with UDL principles and making learning accessible for all. The process of UDL consists of four stages: setting goals, analyzing status, applying UDL and teaching and evaluating UDL, as given in figure 1 (Triana & Supena, 2023). Based on ‘what’, ‘why’ and ‘how’ of learning, CAST (2024) has proposed UDL guidelines consisting of nine guidelines and a number of checkpoints distributed over nine guidelines, as shown in figure 02 (Almeqdad, Aladat, Alquraan, Mohaldat & Al-Makhzoomy, 2023; CAST, 2024). CAST, through research, development and educational practices, facilitated to understand diversity and use technology to optimize learning progress (Edyburn, 2005).

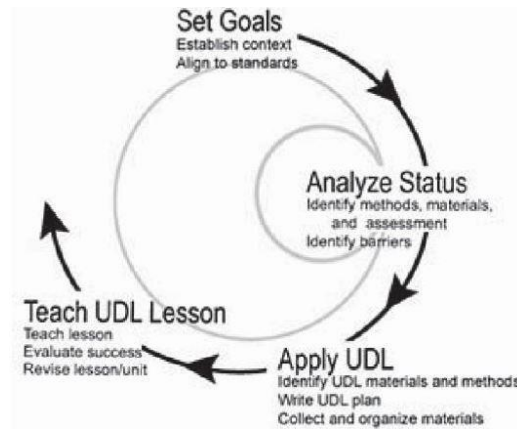


Figure 1. UDL learning framework (Hall et al., n.d.: as cited in Triana & Supena, 2023)

Universal Design for Learning Guidelines

The goal of UDL is **learner agency** that is purposeful & reflective, resourceful & authentic, strategic & action-oriented.

	Design Multiple Means of Engagement →	Design Multiple Means of Representation →	Design Multiple Means of Action & Expression →
Access	Design Options for Welcoming Interests & Identities (7) <ul style="list-style-type: none"> Optimize choice and autonomy (7.1) > Optimize relevance, value, and authenticity (7.2) > Nurture joy and play (7.3) > Address biases, threats, and distractions (7.4) > 	Design Options for Perception (1) <ul style="list-style-type: none"> Support opportunities to customize the display of information (1.1) > Support multiple ways to perceive information (1.2) > Represent a diversity of perspectives and identities in authentic ways (1.3) > 	Design Options for Interaction (4) <ul style="list-style-type: none"> Vary and honor the methods for response, navigation, and movement (4.1) > Optimize access to accessible materials and assistive and accessible technologies and tools (4.2) >
Support	Design Options for Sustaining Effort & Persistence (8) <ul style="list-style-type: none"> Clarify the meaning and purpose of goals (8.1) > Optimize challenge and support (8.2) > Foster collaboration, interdependence, and collective learning (8.3) > Foster belonging and community (8.4) > Offer action-oriented feedback (8.5) > 	Design Options for Language & Symbols (2) <ul style="list-style-type: none"> Clarify vocabulary, symbols, and language structures (2.1) > Support decoding of text, mathematical notation, and symbols (2.2) > Cultivate understanding and respect across languages and dialects (2.3) > Address biases in the use of language and symbols (2.4) > Illustrate through multiple media (2.5) > 	Design Options for Expression & Communication (5) <ul style="list-style-type: none"> Use multiple media for communication (5.1) > Use multiple tools for construction, composition, and creativity (5.2) > Build fluencies with graduated support for practice and performance (5.3) > Address biases related to modes of expression and communication (5.4) >
Executive Function	Design Options for Emotional Capacity (9) <ul style="list-style-type: none"> Recognize expectations, beliefs, and motivations (9.1) > Develop awareness of self and others (9.2) > Promote individual and collective reflection (9.3) > Cultivate empathy and restorative practices (9.4) > 	Design Options for Building Knowledge (3) <ul style="list-style-type: none"> Connect prior knowledge to new learning (3.1) > Highlight and explore patterns, critical features, big ideas, and relationships (3.2) > Cultivate multiple ways of knowing and making meaning (3.3) > Maximize transfer and generalization (3.4) > 	Design Options for Strategy Development (6) <ul style="list-style-type: none"> Set meaningful goals (6.1) > Anticipate and plan for challenges (6.2) > Organize information and resources (6.3) > Enhance capacity for monitoring progress (6.4) > Challenge exclusionary practices (6.5) >

Figure 2. CAST UDL guidelines (CAST, 2024)

The implementation of UDL may involve some major challenges such as preserving and improving the application of UDL keeping in view the unique school context (Sulaiman & Tahar, 2024). Other challenges include learner variability in the classroom. It not only includes differences among students related to their background characteristics and abilities (e.g., culturally diverse students, special educational needs, language competence) but it also encompasses the approach adopted by students to complete a task, interaction and communication skills of students, and the information processing skill of students. Developing lesson plans keeping in view the academic standards and the varied learning needs of students is a common challenge for teachers (Rao & Meo, 2016). Some instructional barriers included strategies used by teacher posing challenges to learning process, lesson mismatching with the present level of skill of learners, unclear relevance of content with student lives, a large quantity of difficult and complex material, course/lesson/assignment outcomes insufficient to explain students about performance expectations, and other academic/psychological/emotional disability (Mackey, Takemae, Foshay & Motesano, 2023). Collaboration and continuous communication among school stakeholders can be helpful to facilitate the implementation of UDL in the given school settings (Sulaiman & Tahar, 2024).

UDL provides learning opportunities for all students (Barteaux, 2014). While UDL considers all the learners in the learning process, UDL does not lower the expectations and criteria for student learning (Dyjur & Jivani, 2024). The contact time between teacher and student (live or face-to-face) is significant, in which the student can work on less challenging lower-order thinking task to more challenging higher-order thinking skills as given in various levels of Bloom's taxonomy (Wells, 2022). UDL benefits students and teachers equally by creating a community of learners. A teacher create safe, compassionate and flexible learning environment where students can experience the curriculum through UDL (Barteaux, 2014). It was noticed in the systemic review that there was a trend on the learning process, student engagement and participation. However, there was a need to focus more learning outcomes (Ewe & Galvin, 2023). The basic purpose of this project idea is to develop understanding the effectiveness of conducting Project Based Learning in schools of Pakistan as an initiative to bring reform and improvements in primary and elementary school systems, which will alternatively enhance the mode of education at a competitive level.

Methodology

Research Settings and Demographic of Participants

The study utilized quantitative research design with one-group pretest-posttest experimental research method. In this study, the independent variable was UDL infused instruction whereas the student performance was the dependent variable. Study followed

the guidelines of UDL mentioned on page# 2-3 of this paper. This project was conducted in the “NUST Creative Learning School” Islamabad, Pakistan. The project was conducted on 23 students (14 boys and 9 girls) of grade 5. One intact group of students of grade 5 in NUST Creative Learning School (NCLS), Pakistan was involved in this study. The duration of the study was 04 weeks. Classroom was equipped with high-definition multimedia. The UDL instruction was embedded in science subject of topics “Plants” and “Human Ear”. All students belonged to high/middle class socio-economic background. An experimental study was conducted in the class in which students of experimental/treatment group received UDL infused instruction.

Research Design

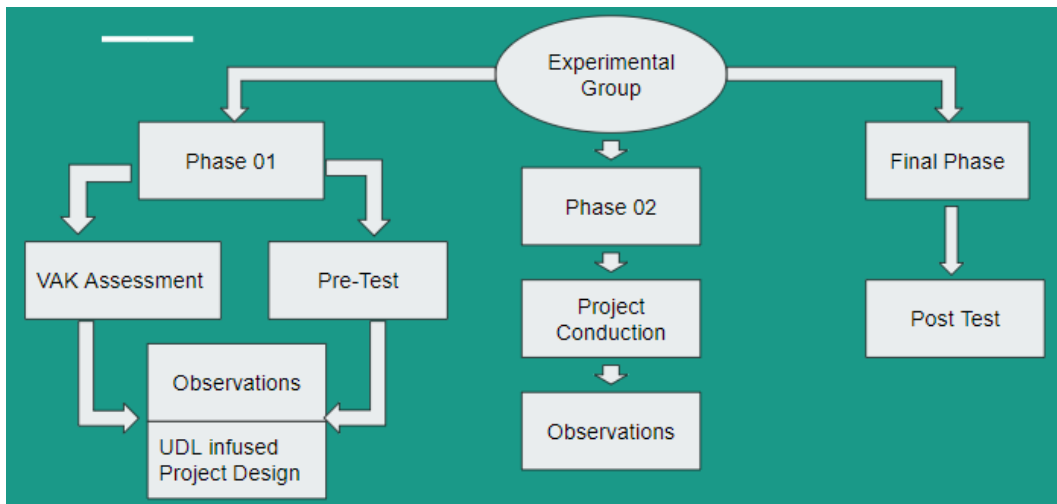


Figure 3. *Research design flow for study*

The methodology designed for this research was based on the experimental research method. The research aimed at analyzing the effectiveness of UDL infused lesson planning and project design on learning factor of participants involved. Research participants were first tested for their learning styles through VAK (Visual Audio Kinesthetic Learning) assessment to check their individual learning styles. This assessment helped in further planning of project design and students’ preferences. During the same phase, individual Pre-tests were also conducted to determine the level of students’ previous and present knowledge and understanding of chosen topics (Plants and Human Ear).

Research Phases

One intact group of students of grade 5 in NUST Creative Learning School (NCLS), Pakistan was involved in this study. The research study included the following two phases in which pre-test and posttest data were collected. Teacher-made tests were used for pre-test and posttest. It was validated through experts' opinion. All of the participants in the experimental group were treated by carrying the whole process with UDL infused instructions and project facilitation, throughout these two phases with some limitations discussed in the later section.

- (i) Pre Intervention- Phase 1: This phase included the following two main methods discussed.

Visual Audio Kinesthetic (VAK) Learning Styles Assessment: To cater and facilitate a variety of learners in a single classroom is the essence of UDL compliant learning (Hazmi & Ahmad, 2018). For this purpose, a simple and understandable Visual Audio Kinesthetic (VAK) Learning Styles Assessment was designed by the research team and conducted. This assessment was based on a questionnaire obtained from (TEAL center staff, 2010) having understandable (30) MCQs appropriate for participants' age level. VAK styles were determined by these results as given in table 1. The project was designed and modified according to these results and different learning styles of students.

Table 1

VAK Assessment Results

Visual Learners	Auditory Learners	Kinesthetic Learners	Multimodal Learners
5	4	4	(Kinesthetic+Visual) = 4 (Visual+Auditory) = 1 (Auditory+Kinesthetic) = 1
6			

Pre-Test: Pre-test of both topics “Human Ear and Plants” were conducted to check the prior knowledge of participants. There are 18 multiple-choice questions (MCQs) in ‘Human Ear’ pretest and 15 multiple-choice questions (MCQs) in ‘Plants’ test. Test results were not much satisfactory especially for the topic “Human Ear” as students did not study it before. They did well in ‘Plants’ pre-test because students studied this topic in their previous grades. Quantitative data were collected through these tests.

Observations: During taking VAK assessment, pre-test and daily discussions, the team observed the working and communication styles of participants to determine the ways each of them tend to learn things (listening, observing or doing). Participants were asked to convey possible hurdle, difficulty or barrier they may face in learning particularly science subjects. Some of the students demonstrated their difficulties with the help of diagrams, some wrote it and some of them just told the team verbally. This qualitative data helped in determining their learning barriers and assisted the team in improving project design and lesson plan.

Planning UDL infused Project and Lesson: After gathering all of the Pre-intervention data, the team started to design the lesson which was based on following UDL principles:

Table 2

UDL Principles infused in designing Projects and Lessons Plans

Principles	Projects and Lesson plans
Multiple means of Representation	Demonstration of Plants and Human Ear Project through Textbook, Living Plants, Videos, Images, Word Wall, Drawings and On-time demonstration by team members.
Multiple means of Engagement	Interactive Videos, Choice of flowers and plants to grow, Collaboration and discussion, Ongoing feedback, formative assessments/demonstrations on a whiteboard, Timely reminders.
Multiple means of Action and Expression	Autonomy to work individually or in the group, Choice of expressing understanding (On the whiteboard, Verbal, Drawings, practical, etc.). Digital media availability (Laptops) to each group.

(ii) During Intervention- Phase 2: Two projects were conducted to validate the results and study learning effectiveness as the result of this research study. One of the projects was “Plants” and other one was “Human Ear”.

Project 1: The first project was of the topic “Plants”. Students in all of the groups researched and discussed Plants among their group members. Students were provided with Laptops. They explored parts of the plants and short videos and demonstrations to learn the procedure to grow plants. Students built their word wall for each difficult word, discussed it with facilitator and project partners. Then students implanted living plants in their school garden. For this activity, they were given autonomy to work individually or with their partners. In the end, they demonstrated their learning by whatever means they

prefer i.e., by oral presentation through hand gesture, drawings, and on whiteboard. Ongoing feedback and facilitation were provided.

Project 2: The next project was “Human Ear”. Students researched and explored major parts and functions of human ear through videos. Students constructed and demonstrated a model of human eardrum. Students were provided with laptops, they watched instructional video to construct the model and then the guidance was removed. Students were provided with necessary material to construct the product themselves. Ongoing feedback and facilitation was also provided here.

Observations: Kinesthetic learners were more engaged but the other learners were equally motivated to outperform others when provided with the opportunity to work in their own way. They were engaged and physically involved in collaboration and knowledge sharing. They seemed to build their own knowledge by making connections and picking up critical details from different modes of representations.

(iii) Post-Intervention- Final Phase

Post-Test: At the end of the study, post-tests were conducted same as pre-test to check students’ conceptual understanding. There was a significant improvement in student’s results, especially on ‘Human Ear’ test. All type of learners improved their results but for kinesthetic learners, it was remarkable.

Results

The significant improvement was observed in test scores of participants through UDL embedded Project based Learning in both lessons (Human Ear and Plants). The Wilcoxon Signed Rank test was applied to determine the improvement in performance of participants because the data of both lessons were not normally distributed, as shown in figure 2-5.

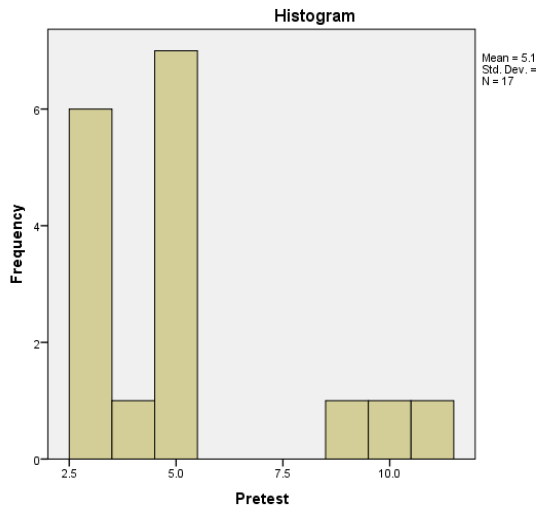


Figure 2. Histogram results of pre-test on 'human ear'

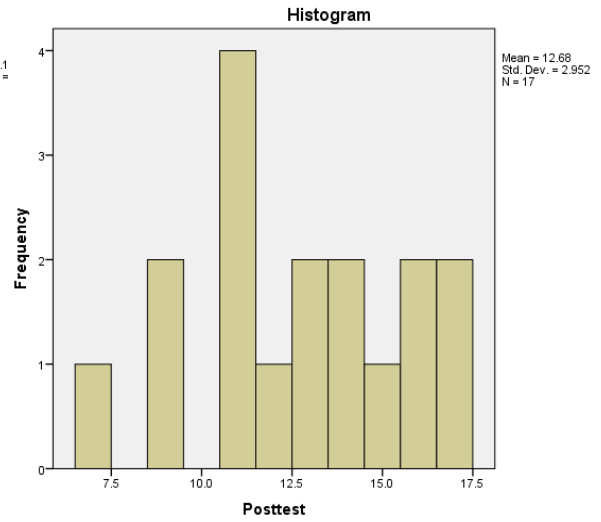


Figure 3. Histogram results of post-test on 'human ear'

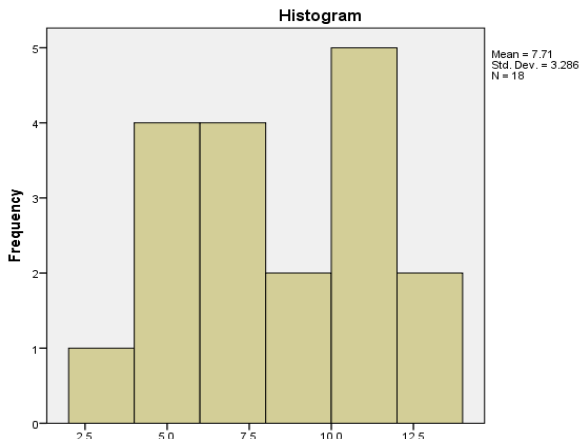


Figure 4. Histogram results of pre-test on 'plants'

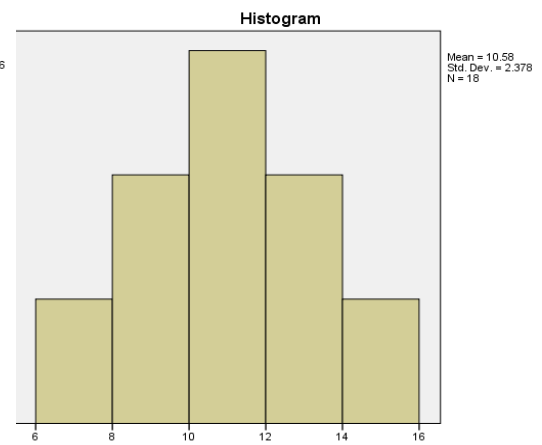


Figure 5. Histograms result of post-test on 'plants'

Table 3

Tests of Normality for test data about human ear

Test	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistics	df	Sig. value	Statistics	df	Sig. value
Pretest	.342	17	.000	.758	17	.001
Posttest	.127	17	.200	.957	17	.577

Table 4

Tests of Normality for test data about plants

Test	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistics	df	Sig. value	Statistics	df	Sig. value
Pretest	.153	18	.200	.938	18	.263
Posttest	.097	18	.200	.987	18	.993

Normality tests, as shown in table 3 and 4, did not show significant value p-value < 0.05 for both lesson results so there is no normal distribution of data in both result sets. So, we have selected Wilcoxon Signed Rank test for analysis of data that is not normally distributed (skewed data).

Table 5

Wilcoxon signed-rank test for comparison of pre and post-test mean scores about 'Human Ear'

Test	N	Mean	SD	Wilcoxon Signed Rank test	p value
Pre-test	17	5.12	2.52	3.623	0.000
Post-test	17	12.68	2.95		

Table 5 showed a comparison of pre- and post-test scores of experimental group on human ear. The significance value for the Wilcoxon signed-rank test depicted a statistically significant difference between the pre- and post-test on plants with the highest mean score of post-test. Majority of results of pre-test < 7; less knowledge of learners about selected topic while there is a significant change in post-test >10. It is inferred that the post-test mean score performance of the experimental group was statistically significant and higher than its pre-test mean score performance.

Table 6

Wilcoxon signed-rank test for comparison of pre and post-test mean scores on 'Plants'

Test	N	Mean	SD	Wilcoxon Signed Rank test	p value
Pre-test	18	7.71	3.286	2.865	0.004
Post-test	18	10.58	2.378		

Table 6 showed a comparison of pre- and post-test scores of experimental group on plants. The significance value for the Wilcoxon signed-rank test depicted a statistically significant difference between the pre- and post-test on plants with the highest mean score of post-test. Results show that students already had prior knowledge about the topic; in post-test, an increase in post-test score was observed between 10 to 12. It is inferred that the post-test mean score performance of the experimental group was statistically significant and higher than its pre-test mean score performance.

Discussion

The study results reported an improvement in the academic performance of students. King-Sears et al. (2023), based on their meta-analysis of twenty studies, stated that students receiving UDL instruction had improved academic performance. It is important to keep in mind while implementing UDL the opportunities and limitations associated with the activities, instructional methods and materials employed for a class or course. Thoma et al. (2023), based on the qualitative content analysis in a STEAM project involving Universal Design Learning (UDL) framework and connectivism, reported about improvement in the learning process, active participation of primary school students, and self-assessment by students. It is important part of the instructional process to keep track of students' learning progress. Roski et al. (2024), Rao et al., (2023) and Burgstahler (2023) viewed UDL framework as a source of reducing barriers for all learners in the learning environment through guiding for informal and formal learning opportunities (Burgstahler, 2023).

The results of this study showed that UDL was successful in building the content expertise of the learners more than the traditional teaching. It was reported that by providing the personalized learning environment, learning support, developing thinking skills of students and assessing their progress, teachers can help their students to grow as expert learners. A student facing problem in learning process, can grow as an expert learner through achieving learning outcomes, use of accessible learning materials and development of knowledge and skills through self-directed activities (Navaitienė & Stasiūnaitienė, 2021).

Conclusion

This study examines the implementation of UDL framework in Project Based Learning in subject of science for grade 5. This approach appeared as useful in catering all type of learners. The students were mostly kinesthetic learners, so they were very keen to perform the projects. They learned more by engaging in the process of learning the role of eardrum and how plants grow by doing projects. The students' participation was more while performing the tasks of projects than in traditional teaching methodology. The

performance of majority of the students is improved in post-test. It showed that, with fun and engagement, participants learned new things and could relate the book content with real world. Visual learners were observing the tasks done by themselves or by the fellow students and grasp the concepts and facts. Moreover, students were watching the videos with great interest and discussed the things being shown in videos with fellows. This increased the peer learning process. The approach was student-centered and open to discussion while the team demonstrated the topics they were going to cover. This kind of making in education increased students' motivation and engagement level as well as increased the learning outcomes. Project Based Learning specifically infused with UDL Framework made the learning active unlike the lecture-based learning that encourages the passive learning.

As the intervention begun, school just started its new session and they had a fixed and strict timetable to follow so the classes allotted for intervention were of games and sports periods. Students, especially boys, wanted to play outside. Students had to concentrate a lot to hear the voice in videos because there was a lot of disturbance and noise outside. Few students were absent in almost each intervention day, somehow this influenced the result data. Due to the unavailability of tools for plantation, students had to compromise on the way real plantation is actually done. These factors can be availed as an opportunity for further research in future. The projects should be conducted in free class time or in arts period so students don't miss their other activities time. While performing the projects, instructor make ensure the availability tools/equipment required before-hand. This study can work as a base for researchers who want to explore the implementation of UDL principles while conducting project based learning at primary level. The educators must also be trained how to incorporate student-centered learning by using UDL principles.

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