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Effectiveness of Flipped Classroom – Project-Based Learning (FC-PjBL) Hybrid Approach on Student Performance in General Biology

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Abstract. Both the Flipped Classroom Approach (FCA) and the Project-Based Learning (PjBL) approaches have gained attention in the K-to-12 education. However, exploration of the impact of hybridizing these two teaching approaches was limited, particularly in Biology teaching in Senior High School. The study aimed to determine the effectiveness of the Flipped Classroom-Project-Based Learning (FC-PjBL) Hybrid Approach on the performance level of General Biology students in a Public National High School in the Municipality of Polomolok. A quasi-experimental One-Group Pretest-Posttest Design was used to determine differences in learning outcomes. A convergent parallel mixed-method design was used to analyze quantitative and qualitative data, leading to data integration and the development of a pedagogical model. A validated teacher-made test, lesson exemplars, and video materials were used for 108 Grade 12 Science, Technology, Engineering, and Mathematics strand students. A Focus Group Discussion (FGD) was also conducted to capture students' experiences with the FC-PjBL Hybrid Approach. In data integration, the Joint Display Analysis was used to link the qualitative and quantitative data. The study's findings revealed that students' performance in content areas and cognitive skills was Moderately Mastered to Highly Mastered, and there was a significant difference in the mean scores before and after implementation. This implies that the FC-PjBL Hybrid Approach is efficacious in improving students' performance. Qualitative findings revealed key learning benefits, including streamlined, empowered, and reflexive learning; constructive feedback; experiential learning; and the development of 21st-century skills. Based on the integration of results, the FC-PjBL Hybrid Approach Pedagogical Model was conceptualized to improve students' learning and experiences in General biology. The findings suggest that this hybrid approach is an effective instructional strategy for improving students' performance and fostering holistic growth.

Keywords: Content mastery; Cognitive skills; Flipped classroom approach; Pedagogical model; Project-based learning.

1.0 Introduction

The rapid changes in education and technology make teaching in today's classroom more complex and challenging. As a result, teachers should have an extensive repertoire of skills in implementing these technologies in the classroom. According to the International Society for Technology in Education (ISTE, 2019), educators should continually improve their practice by learning from and with others and exploring proven and promising practices that leverage technology to improve student learning. Thus, teachers are encouraged to implement and practice new approaches to teaching that develop critical and creative thinking by integrating technology and

other learning resources to address learning goals (Research Center for Teacher Quality [RCTQ], 2019). However, all of these will be unattainable if teachers are not equipped with innovative approaches in K-to-12 education, such as the Flipped Classroom Approach (FCA) and Project-based Learning (PjBL) in teaching Biology.

The flipped classroom approach is a pedagogical model in which students watch video lessons or engage in online learning on their own time and in their own space. In contrast, class time is dedicated to individual support and to developing higher-level engagement (Neiss & Gillow-Wiles, 2015). On the other hand, Project-based Learning (PjBL) involves learners designing, developing, and constructing hands-on solutions to a problem (Boston University – Center for Teaching and Learning, 2023). The flipped classroom is becoming an increasingly popular teaching method in mathematics education in Saudi Arabia to address low mathematics achievement as measured by the Trends International Mathematics and Science Study (TIMSS) (Algarni & Lortie-Forgues, 2022). In contrast, Project-Based Learning (PjBL) has been embraced by Kazakhstan as one of the strategies for teaching students the skills to participate in the global economy (McCarthy, 2016). Both models showed positive results, such as active participation and independence, sense of responsibility, development of critical thinking skills, and motivation to learn according to their own time and space in the Flipped Classroom Approach (Utami, 2024) and improved students' self-efficacy in the Project-Based Learning (Samsudin et al., 2020).

In the Philippines, both pedagogical models are encouraged by educational leaders for classroom use, as stipulated in the Conceptual Framework of Science Education in the K to 12 Curriculum. However, some teachers and pre-service teachers in the Philippines are unaware of, or do not understand, the flipped classroom approach (Dayagbil et al., 2017). In the case of Project-Based Learning, few studies assess its implementation in Philippine Schools (Babia & Candia, 2021). The lack of awareness and non-implementation of these two pedagogical models may be attributed to a lack of training and experience, perceived benefits, resource availability, time constraints, insufficient administrative support, and difficulties in designing and assessing learning activities. These could be one of the underlying reasons for the poor results of the Philippines in TIMSS (2020) where the Philippines scored below the international average in science among 4th Grade pupils and in the Program for International Student Assessment (PISA, 2023), where the Philippines scored lower in reading, mathematics, and science among fifteen-year-old students which is below the OECD average. The laggard status in international assessment is multifactorial and cannot be solely blamed on the pedagogical models. However, the World Bank (2023) reported that 66% of teachers observed in the Philippines had a "medium-low" level of effective teaching practices, while none were observed to have a "high" level of effective pedagogy.

As the Department of Education advances reforms through the MATATAG agenda, one of its goals is to support teachers to teach better (DepEd – MATATAG Agenda, 2023). While previous studies explored the individual impact of FCA and PjBL models, this study differs by hybridizing the two approaches tailored for Senior High School Biology. Moreover, the study employs a mixed-methods design that not only measures performance but also captures students' experiences in developing a contextualized pedagogical model. This research seeks to answer the following questions: What is the performance level of General Biology students in the pretest and posttest in Biomolecules in terms of content and cognitive skills in the following content areas: (a) carbohydrates; (b) lipids; (c) proteins; and (d) nucleic acids? Is there a significant difference in the performance level of General Biology students in the pretest and posttest across content areas and cognitive skills? How do the students describe their experiences in the flipped-classroom project-based learning (FC-PjBL) Hybrid Approach? What meta-analysis can be derived from the quantitative and qualitative data? Based on the findings of the study, what pedagogical model could be designed to teach the topic of Biomolecules?

2.0 Methodology

2.1 Research Design

This study used a quasi-experimental One-Group Pretest-Posttest Design to assess the effectiveness of the Flipped Classroom-Project-Based Learning (FC-PjBL) Hybrid Approach. The design involves administering a treatment to a single group and measuring the effects before and after the intervention without a control group to show the differences in learning outcomes. The continuous assessment before, during, and after the intervention was done to measure the effectiveness of the flipped-classroom Project-Based Learning (FC-PjBL) Hybrid Approach. Table 1 presents the study's research design.

Table 1. *Quasi-Experimental with One-Group Pretest-Posttest Design*

Sections	O (Pre-test)	X (Treatment)	O (Post-test)
Section A	Teacher-made Test	FC-PjBL	Teacher-made Test
Section B	Teacher-made Test	FC-PjBL	Teacher-made Test
Section C	Teacher-made Test	FC-PjBL	Teacher-made Test

Quantitative data were collected using the teacher-made test to assess content mastery and cognitive skills. The data were analyzed using the *N*-gain formula and a dependent sample *t*-test. Focus group discussions (FGDs) were conducted to explore students' experiences with the FC-PjBL hybrid approach. Additionally, a convergent parallel mixed-methods design was employed to collect and analyze quantitative and qualitative data separately, then integrated through Joint Display Analysis (Fretters & Gutterman, 2021). The integration of data was achieved through a table presenting the quantitative results and the qualitative themes and patterns of convergence or divergence from the integration, which were identified to provide an understanding of the effectiveness of the FC-PjBL hybrid approach.

2.2 Research Locale

This research was conducted in a public national high school in the Polomolok West District, Municipality of Polomolok, Province of South Cotabato, that offers a Senior High School Program, specifically the Science, Technology, Engineering, and Mathematics (STEM) strand.

2.3 Research Participants

The study's respondents were 108 Grade 12 students from a public national high school in Polomolok West District, specifically those who had a General Biology subject in the first semester of the school year 2024 to 2025. The respondents of the study were all the students enrolled in the Science, Technology, Engineering, and Mathematics (STEM) strand of the K to 12 Basic Education Program in Polomolok West District. Additionally, purposive sampling was used to select a subset of students for the Focus Group Discussion (FGD) to determine their experiences with the Flipped Classroom – Project-Based Learning (FC-PjBL) hybrid approach.

2.4 Research Instrument

To measure the students' performance using the Flipped Classroom – Project-Based Learning (FC-PjBL) hybrid approach, a teacher-made test was used. This tool evaluated the students' performance in General Biology, specifically in various topics in Biomolecules, such as (a) carbohydrates, (b) lipids, (c) proteins, and (d) nucleic acids.

The teacher-made test was constructed and aligned with the Learning Competencies (LC) in accordance with the Department of Education (DepEd) specifications. A Table of Specifications (TOS) was developed to check the alignment and the cognitive skills involved. During validation of the teacher-made test, three validators assessed its content and face validity. The validation rating for the teacher-made test was 4.00 (Highly Valid). After validation, a first trial run was conducted with 38 Grade 12 students at a private secondary school who had already completed the General Biology subject. After the first trial run, an item analysis was conducted until a teacher-made test with 30 multiple-choice items aligned with the competencies and topics assigned by the DepEd remained. Of 80 items on the teacher-made test, 48 were rejected, 15 required revisions, and 17 were retained. The items that required revisions underwent an Option Analysis, which identified the ineffective or conditional distractors that needed revision. In item analysis, the difficulty index (Df) and discrimination index (Ds) were determined.

A second trial run was conducted on the 30-item teacher-made test with another set of 38 Grade 12 students at a private secondary school who had already completed the General Biology subject to determine the test's reliability using the Kuder-Richardson 20. After the second trial run, the KR-20 was 0.93, which was interpreted as Excellent (Stage 1) based on the PKR-20. The 30-item teacher-made test was used to administer pre- and post-tests to determine the effectiveness of the Flipped Classroom – Project-Based Learning (FC-PjBL) Hybrid Approach.

In the qualitative part, a Focus Group Discussion (FGD) guide was used to elicit students' experiences with the implementation of the Flipped Classroom-Project-Based Learning (FC-PjBL) Hybrid Approach. The researcher developed the FGD guide. In validating the FGD guide, three validators assessed its clarity, relevance, appropriateness, and logical flow. In the validation of the FGD guide, the validators suggested the following for the improvement of the guide such as: (1) provide appropriate follow-up questions to explore topics more

thoroughly, (2) start the questions with "How" and do away with "Why" or "Why not" because it is demeaning and it implies demanding for answers, (3) rephrase and restate some questions, (4) avoid the use of technical terms which are pedagogical (e.g. critical thinking, Flipped Classroom Approach), (4) ensure that questions were arranged into thematic sections to guide the flow of the discussion, (5) start with broader topics and gradually move to more specific, and (6) administer the question to the researcher itself to preempt follow up questions and conduct pilot testing of the FGD guide twice to a small group of students. After expert validation, the FGD guide received a validation rating of 4.11 (Highly Valid). After the pilot testing of the FGD guide to the small group of students, the following modifications were made (1) revising some technical terms used in the guide such as "motivation" to "excite" or "enjoyable", (2) removal of questions that provide similar responses, (3) addition of follow-up questions that help in the exploration of the topics, and (4) rearranging some questions based on thematic sections. In data analysis and interpretation of the students' responses, Braun and Clarke's 6-Step Thematic Analysis was used, which gives an easily interpretable and concise description of the emergent themes and patterns within a dataset.

2.5 Data Gathering Procedure

The researcher followed the following procedures to gather the pertinent data needed to complete the study.

To measure students' performance, the researcher developed a teacher-made test with a Table of Specifications (TOS) and had it validated by experts. After validation, the teacher-made test underwent two pilot tests to determine its difficulty, discriminatory index, and internal consistency. To determine students' experiences with the Flipped Classroom-Project-Based Learning (FC-PjBL) Hybrid Approach, the researcher developed a Focus Group Discussion (FGD) guide. Experts validated the FGD guide and conducted two trial runs with a small group of students (3 per group). The pilot testing of the FGD guide was conducted after the implementation of the FC-PjBL Hybrid Approach.

The researcher also developed the lesson exemplars for the Flipped Classroom - Project-Based Learning (FC-PjBL) Hybrid Approach following the 7Es (Elicit, Engage, Explore, Explain, Elaborate, Evaluate, and Extend) structure. Experts validated the lesson exemplars to ensure their utmost validity and usability, using the validation tool for lesson exemplars adopted from DepEd SOCCSKSARGEN. For the validation result, the lesson exemplar received a passing rating for content, format, presentation, organization, and the accuracy and up-to-dateness of the information. The teacher used the validated lesson exemplar.

The researcher developed a script for the flipped classroom video materials. During the development of the flipped classroom video materials, Canva for Education was used. The playtime of the flipped classroom videos ranged from 10 to 13 minutes per video. It was saved in an online drive (Google Drive) or on a flash drive and uploaded to group chats (Messenger) for easy access to the materials. The video materials were saved in .mp4 format, ranging in size from 80 to 120 Megabytes, with a video resolution or dimension of 720p (High Definition) and an aspect ratio of 16:9 (Widescreen). The flipped classroom video materials were checked and validated by experts using the validation tool for video lessons adopted from DepEd SOCCSKSARGEN. For the validation results, the flipped classroom video materials received passing ratings for content quality, instructional quality, and technical quality. The teacher and students used the validated flipped classroom video materials. Figure 1 presents a screenshot of the Flipped Classroom Video Materials.

In the implementation of the intervention, the researcher wrote a letter of approval to the Schools Division Superintendent and School Principal to allow the researcher to administer the materials and conduct data gathering specifically for the Grade 12 Science, Technology, Engineering, and Mathematics (STEM) strand students of the K to 12 Basic Education Program in Polomolok 4 District. The researcher used the teacher-made test for the pretest of all participants. The pre-test results were analyzed using the Shapiro-Wilk normality test and the Levene's test for homogeneity of variances. The pre-test data were used to determine students' performance before the use of the Flipped Classroom-Project-Based Learning (FC-PjBL) Hybrid Approach.

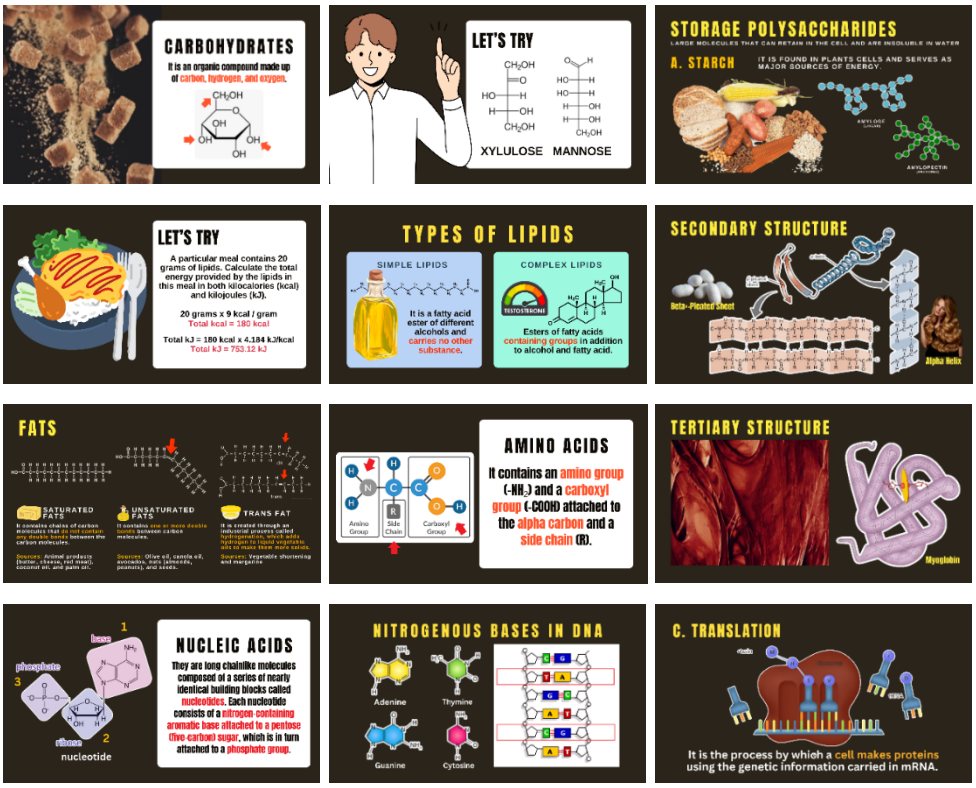

Figure 1. *Screenshot from the Flipped Classroom Video Materials*

During the treatment application, the researcher checked the classrooms to ensure they were free of situational variables. In addition, the researcher supervised the class and prepared other materials for in-class activities to ensure that everything was in order. The teacher demonstrator used the flipped video materials, instructional materials, and lesson exemplars to deliver the topics in General Biology, specifically in Biomolecules.

After the teachers implemented the activities specified in the lesson exemplars, the researcher administered a post-test to all groups. The data gathered in the post-test were used to determine the students' performance after the flipped-classroom Project-based Learning (FC-PjBL) Hybrid Approach was used. The post-test results were reanalyzed using the Shapiro-Wilk normality test and the Levene test for homogeneity. The regular and homogeneous groups underwent a dependent-samples t-test and Cohen's d to determine whether there were significant differences in their performance. In dealing with the data gathered, Ebel and Frisbie's % Range was used to interpret the mean scores of the respondents.

Table 2. *Criteria for the Performance Level of the Respondents in the Study*

Ebel and Frisbie's Percent Range	Qualitative Description	Verbal Interpretation
86 – 100	Very Good	Very Highly Mastered
71 – 85	Good	Highly Mastered
40 – 70	Average	Moderately Mastered
15 – 39	Poor	Less Mastered
0 – 14	Very Poor	Least Mastered

The normalized learning gain (*N*-gain) was used to measure a student's learning improvement from the beginning to the end of a course (Galloway & Lancaster, 2016).

Table 3. *Criteria of Normalized Learning Gain Index (Meltzer, 2002)*

Limitation	Category
$g > 0.7$	High
$0.3 \leq g \leq 0.7$	Medium
$g > 0.3$	Low

To assess the normality of the group, the Shapiro-Wilk test was used. If $W_0 \geq W_{table}$ at $\alpha = .05$, it is normal. The Levene Statistic was used to interpret the homogeneity of the group. If the $F_{count} < F_{table}$ at $F_\alpha = .05$, the interpretation is homogeneous. A dependent sample t-test was used to determine the performance level in content mastery and cognitive skills of the students' pre-test and post-test scores before and after the implementation. If $t_{count} > t_{table}$ at $t_\alpha = .05$, the interpretation is significantly different. Cohen's d was also used to assess the size of the effect when comparing two groups.

Table 4. *Cohen's d Effect Size Interpretation*

Value	Interpretation
$0.20 \geq d \leq 0.50$	Small Effect Size
$0.50 \geq d \leq 0.80$	Medium Effect Size
$d \geq 0.80$	Large Effect Size

Microsoft Excel and IBM SPSS Statistics were used for statistical analysis. The researcher requested the expertise of a statistician for accurate calculations and better data interpretation. The data gathered were collated, interpreted, analyzed, and presented through tables. After the posttest, a Focus Group Discussion (FGD) was conducted to gather students' experiences with the Flipped Classroom-Project-based Learning (FC-PjBL) Hybrid Approach. Before the FGD guide was used with the participants, pilot testing was conducted twice with a small group of students. During the FGD, participants were given an Informed Consent Form in advance. Ten students were purposively selected to participate in the Focus Group Discussion. The audio recording was transcribed and analyzed thematically using Braun and Clarke's 6-Step Thematic Analysis. After the quantitative and qualitative data were collected, the study conducted a meta-analysis using the Joint Display Analysis, aligning the statistical outcomes of the pre-test and post-test scores with the thematic findings from the focus group discussions (FGD) to identify patterns and develop a final theme. A matrix was developed in which the left column displayed quantitative data and the right column qualitative data. Colored arrows were used to represent the link between the qualitative and quantitative outcomes. Based on the combined findings, the final theme and meta-analysis were derived to synthesize the data. Based on the synthesized data, a pedagogical model for the FC-PjBL hybrid approach was developed.

2.6 Ethical Considerations

Several potential ethical issues were considered in conducting the study. The researcher considered the research's consequences for participants to be an important concern. Hence, the school's name and the respondents/participants remained anonymous, and the gathered information remained confidential and stored securely. All respondents or participants were given written information about the research in advance of the data collection, and signed contract forms were collected at the start of the Focus Group Discussion (FGD). All participants were advised of their rights to withdraw or refuse to participate in the research at any stage. Anonymity and confidentiality were assured to all participants, as the researcher was fully aware of Republic Act 10173, the Data Privacy Act of 2012. Approval was obtained from the Institutional Ethics Committee and the school administration to ensure compliance with the ethical guidelines.

3.0 Results and Discussion

3.1 Content Mastery of the Students Before and After the Use of the FC-PjBL Hybrid Approach in Different Content Areas in Biomolecules

Content mastery refers to the students' knowledge and understanding of the subject matter. Tables 5, 6, and 7 present the content mastery and *N*-gain index before and after the use of the FC-PjBL Hybrid Approach in Biomolecules.

The results (see Table 5) showed that Sections A, B, and C, before the implementation of the FC-PjBL hybrid approach, were all classified as Moderately Mastered in the topic Carbohydrates, with Section B achieving the highest mean percentage of 52.52%. In lipids, all three sections were rated Moderately Mastered, with Section C achieving the highest mean percentage of 45.64%. In proteins, section C achieved Moderate Mastery with a mean percentage score of 41.67%, while the remaining sections achieved Less Mastery. In nucleic acids, all sections achieved Less Mastered, with section A scoring the lowest with a mean percentage of 35.14%. The data show that, before implementing the FC-PjBL hybrid approach, students had varying levels of mastery across different content areas in Biomolecules. Hence, the utilization of the FC-PjBL hybrid approach could address this gap.

Table 5. *Students' Content Mastery Before the Use of the FC-PjBL Hybrid Approach in Biomolecules*

Section	Carbohydrates		Lipids		Proteins		Nucleic Acids	
	%	Interpretation	%	Interpretation	%	Interpretation	%	Interpretation
A	41.70	Moderately Mastered	41.70	Moderately Mastered	39.34	Less Mastered	35.14	Less Mastered
B	52.52	Moderately Mastered	42.86	Moderately Mastered	36.60	Less Mastered	36.97	Less Mastered
C	51.19	Moderately Mastered	45.63	Moderately Mastered	41.67	Moderately Mastered	38.89	Less Mastered
$\underline{x}$	48.47	Moderately Mastered	43.40	Moderately Mastered	39.20	Less Mastered	37.00	Less Mastered

Table 6. *Students' Content Mastery After the Use of the FC-PjBL Hybrid Approach in Biomolecules*

Section	Carbohydrates		Lipids		Proteins		Nucleic Acids	
	%	Interpretation	%	Interpretation	%	Interpretation	%	Interpretation
A	73.36	Highly Mastered	72.20	Highly Mastered	64.26	Moderately Mastered	70.27	Highly Mastered
B	76.05	Highly Mastered	72.27	Highly Mastered	64.05	Moderately Mastered	71.43	Highly Mastered
C	77.38	Highly Mastered	72.62	Highly Mastered	63.58	Moderately Mastered	70.63	Highly Mastered
$\underline{x}$	75.60	Highly Mastered	72.36	Highly Mastered	63.96	Moderately Mastered	70.77	Highly Mastered

After implementing the FC-PjBL hybrid approach (See Table 6), the results showed that all sections achieved a Highly Mastered level in the topic Carbohydrates, with section C achieving the highest mean percentage of 77.38%. In lipids, all sections achieved a Highly Mastered level, with section C achieving the highest mean percentage of 72.62%. In proteins, all sections achieved Moderate Mastery, with the mean percentage ranging from 63.58% for section C to 64.26% for section A. In nucleic acid, all sections achieved a Highly Mastered level, with section B achieving the highest mean percentage of 71.43%. This indicates a significant improvement in students' content mastery of carbohydrates, lipids, and nucleic acids. At the same time, mastery of protein content improved, even though it remained at the Moderately Mastered level. Hence, the use of the FC-PjBL hybrid approach demonstrates effectiveness in enhancing content mastery across the topics in Biomolecules.

The study conducted by Sholahuddin et al. (2023) on the use of Project-Based and Flipped Learning in the Classroom showed that implementing flipped classrooms in project-based learning improved students' scientific literacy better than the PjBL model. In addition, the study by Bolivar et al. (2023) on the implementation and benefits of the hybrid methodology found that its use yields significant benefits, leading to more effective learning and a greater preference than the traditional method. Furthermore, in the study by Aydin and Mutlu (2023), the PBL group and the FCM-supported PBL group achieved significantly higher post-test scores than the control group. Hence, the study's results are consistent and confirm that the hybrid methodology fosters a better understanding of the subject matter.

Section	Carbohydrates		Lipids		Proteins		Nucleic Acids	
	Score	Category	Score	Category	Score	Category	Score	Category
A	0.49	Moderate Gain	0.42	Moderate Gain	0.39	Moderate Gain	0.52	Moderate Gain
B	0.53	Moderate Gain	0.48	Moderate Gain	0.43	Moderate Gain	0.48	Moderate Gain
C	0.41	Moderate Gain	0.44	Moderate Gain	0.34	Moderate Gain	0.50	Moderate Gain
$\underline{x}$	0.48	Moderate Gain	0.45	Moderate Gain	0.39	Moderate Gain	0.50	Moderate Gain

Table 7. *Summary Table for Normalized Learning Gain Index in the Use of FC-PjBL Hybrid Approach in Biomolecules*

In the *N*-gain score (See Table 7), all sections and topics are categorized as Moderate Gain. In carbohydrates, the scores range from 0.41 in section C to 0.53 in section B, with an average score of 0.48, and are categorized as Moderate Gain. In lipids, the scores ranged from 0.42 in section A to 0.48 in section B, with an average score of 0.45 categorized as Moderate Gain. In proteins, the scores ranged from 0.34 in section C to 0.43 in section B, with an average of 0.39, categorized as Moderate Gain. In nucleic acids, the scores range from 0.48 in section B to 0.52 in section A, with an average score of 0.50 categorized as Moderate Gain. Hence, utilization, as measured by the normalized learning gain, shows consistent improvement in students' scores after implementing the FC-PjBL hybrid approach. In addition, the N-gain results showed that the approach achieved moderate learning gains across all content areas in Biomolecules. The moderate gain observed in this study can be attributed to various factors such as cognitive load, motivation, and learning adaptation. In the cognitive load theory (Sweller, 1988), the complexity of project-based tasks increases cognitive demands, straining students' memory capacity. This could limit the ability to retain or process information. In addition, some students required more extensive

scaffolding or teacher support to reach their full potential, as defined by Vygotsky's Zone of Proximal Development (ZPD) (Vygotsky, 1978).

3.2 Cognitive Skills of the Students Before and After the Use of the FC-PjBL Hybrid Approach in Different Content Areas in Biomolecules

Cognitive skills focus on the ability to apply their learning and analyze the information presented. Tables 8, 9, and 10 present the cognitive skills and *N*-gain index before and after the use of the FC-PjBL Hybrid Approach in Biomolecules.

Table 8. *Students' Cognitive Skills Before the Use of the FC-PjBL Hybrid Approach in Biomolecules*

Section	Knowledge		Comprehension		Application		Analysis	
	%	Interpretation	%	Interpretation	%	Interpretation	%	Interpretation
A	39.19	Less Mastered	45.05	Moderately Mastered	36.68	Less Mastered	32.43	Less Mastered
B	47.35	Moderately Mastered	40.52	Moderately Mastered	42.02	Moderately Mastered	30.88	Less Mastered
C	46.94	Moderately Mastered	43.83	Moderately Mastered	42.86	Moderately Mastered	40.28	Moderately Mastered
$\underline{x}$	44.49	Moderately Mastered	43.12	Moderately Mastered	40.52	Moderately Mastered	34.53	Less Mastered

Table 9. *Students' Cognitive Skills After the Use of the FC-PjBL Hybrid Approach in Biomolecules*

Section	Knowledge		Comprehension		Application		Analysis	
	%	Interpretation	%	Interpretation	%	Interpretation	%	Interpretation
A	70.27	Highly Mastered	66.67	Moderately Mastered	70.66	Highly Mastered	72.97	Highly Mastered
B	72.35	Highly Mastered	65.36	Moderately Mastered	71.85	Highly Mastered	75.00	Highly Mastered
C	73.33	Highly Mastered	68.21	Moderately Mastered	67.06	Moderately Mastered	75.00	Highly Mastered
$\underline{x}$	71.98	Highly Mastered	66.75	Moderately Mastered	69.86	Highly Mastered	74.32	Highly Mastered

The results (see Table 8) showed diverse results in cognitive skills before the implementation of the FC-PjBL hybrid approach. In the knowledge level, the student demonstrated a Moderately Mastered performance with a mean percentage of 44.49%, but in the three sections, only section A scored the lowest at 39.19% (Less Mastered). At the comprehension level, all sections achieved a Moderately Mastered performance with a mean percentage score of 43.12%. At the application level, all sections achieved a Moderately Mastered performance, with a mean percentage score of 40.52%; however, only section A scored the lowest at 36.68% (Less Mastered). At the analysis level, all sections achieved a Less Mastered performance with a mean percentage score of 34.53%. The data shows that those students performed well at the knowledge and comprehension levels but struggled with the application and analysis levels, indicating weaker performance in Higher-Order Thinking Skills (HOTS). Hence, the use of the FC-PjBL hybrid approach could address the gap in application and analytical thinking.

After implementing the FC-PjBL hybrid approach (See Table 9), the results showed that all sections achieved the Highly Mastered level, with a mean percentage of 71.98%. At the comprehension level, all sections achieved a Moderately Mastered level, with a mean percentage score of 66.75%, indicating significant growth compared to the pre-test scores. At the application level, sections A and B achieved a Highly Mastered level, with mean percentage scores of 70.66% and 71.85%, respectively, while section C scored 67.06%, indicating a Moderately Mastered level. However, at the application level, all sections achieved a Highly Mastered level, with a mean percentage score of 69.86%, reflecting a substantial improvement over pre-test scores. At the analysis level, all sections achieved the Highly Mastered level with a mean percentage score of 74.32%. Hence, the results showed that the FC-PjBL hybrid approach improves students' knowledge of the subject matter and enhances Higher-Order Thinking Skills (HOTS) across the biomolecules topics.

In the study conducted by Andrini et al. (2019) on the effects of flipped classrooms and project-based learning models on students' critical thinking ability, the study revealed positive effects on critical thinking, including elementary clarification, basic support, inference, advanced clarification, strategy, and tactics. In addition, the study by Novfitri et al. (2024) supported that of Andrini et al. (2019), showing that a project-based flipped learning model is effective for early childhood cognitive development. Together, these findings reinforced the study's finding that the use of the FC-PjBL hybrid approach promotes cognitive growth and a deeper understanding of the different content areas.

Table 10. *Summary table for Normalized Learning Gain Index in the Use of FC-PjBL Hybrid Approach in Biomolecules*

Section	Knowledge		Comprehension		Application		Analysis	
	Score	Category	Score	Category	Score	Category	Score	Category
A	0.50	Moderate Gain	0.36	Moderate Gain	0.54	Moderate Gain	0.61	Moderate Gain
B	0.45	Moderate Gain	0.39	Moderate Gain	0.48	Moderate Gain	0.62	Moderate Gain
C	0.50	Moderate Gain	0.40	Moderate Gain	0.42	Moderate Gain	0.44	Moderate Gain
$\underline{x}$	0.48	Moderate Gain	0.38	Moderate Gain	0.48	Moderate Gain	0.56	Moderate Gain

In the *N*-gain score (See Table 10), all sections and cognitive levels achieved a Moderate Gain. At the knowledge level, the mean score was 0.48, which was categorized as Moderate Gain; sections A and B achieved the highest *N*-gain of 0.50 (Moderate Gain). At the comprehension level, the scores ranged from 0.36 in section A to 0.40 in section C, with an overall average score of 0.38, which was categorized as a Moderate Gain. At the application level, the average *N*-gain was 0.48, which was categorized as a Moderate Gain; in which section A achieved the highest *N*-gain of 0.54 (Moderate Gain). At the analysis level, the overall average *N*-gain was 0.56, which was categorized as a Moderate Gain; in which section B achieved the highest *N*-gain of 0.62 (Moderate Gain). Hence, across all sections and cognitive skills involved, the normalized learning gain scores demonstrate a consistent improvement in cognitive skill levels among students after implementing the FC-PjBL hybrid approach. In addition, the N-gain results indicated that the FC-PjBL hybrid approach effectively enhanced students' higher-order thinking skills (HOTS). The moderate gain could also be attributed to variations in students' motivation to learn the content at their own time, pace, and place, with some students being motivated. In contrast, others struggle during the self-learning phase, leading to moderate *N*-gain. Overall, the moderate *N*-gain effectively enhanced content mastery and cognitive skills, but cognitive demands and students' motivation prevented them from achieving higher *N*-gain scores.

3.3 Significant Difference in the Performance Before and After the FC-PjBL Hybrid Approach in Different Content Areas and Cognitive Skills

The following sections present the significant difference in students' content mastery and cognitive skills before and after the implementation of the FC-PjBL hybrid approach. Tables 11 and 12 reveal the summary of the normality test using the Shapiro-Wilk test, which is essential in determining if the dataset follows a typical distribution pattern, and the homogeneity test using Levene's test for equality of variances, which is important to determine if the groups have equal variances.

Table 11. *Summary of Normality Test Using the Shapiro-Wilk Test*

Section		Shapiro-Wilk			Conclusion
		Statistic	df	Sig.	
A	Pretest	0.968	37	0.364	Normal
	Post-test	0.983	37	0.826	Normal
B	Pretest	0.944	34	0.081	Normal
	Post-test	0.974	34	0.591	Normal
C	Pretest	0.965	36	0.299	Normal
	Post-test	0.069	36	0.399	Normal

The Shapiro-Wilk test in section A for the pre-test resulted in p-values of 0.364, respectively, while the post-test *p*-values were 0.826. Similarly, section B achieved pre-test *p*-values of 0.081 and post-test *p*-values of 0.591. For section C, the pre-test results showed a p-value of 0.299, and the post-test results showed a p-value of 0.399. Based on the normality tests, all sections yielded p-values> 0.05. This indicates that the null hypothesis was accepted and the data are typically distributed. Hence, parametric statistics, such as dependent-samples t-tests, can be used for further analysis.

Table 12. *Summary of Homogeneity Test Using Levene's Test for Equality of Variances*

Section		df	Mean	SD	F	Sig	Conclusion
A	Pretest	37	11.838	2.995	1.609	0.209	Homogeneous
	Post-test	37	20.892	3.828			
B	Pretest	34	12.559	3.164	2.358	0.129	Homogeneous
	Post-test	34	21.147	4.172			
C	Pretest	36	13.250	3.475	0.591	0.445	Homogeneous
	Post-test	36	21.167	3.212			

Levene's test in section A yielded an *F*-value of 1.609 with a *p*-value of 0.209, while in section B, the *F*-value was 2.358 and the *p*-value was 0.129. In section C, the *F*-value was 0.591, and the p-value was 0.445. The results of Levene's test revealed that all sections are homogeneous, and they satisfy the key assumptions for parametric statistics, such as the use of dependent sample t-tests.

Tables 13 and 14 present the summary of the dependent-samples t-test for students' performance before and after the flipped-classroom project-based learning (FC-PjBL) Hybrid Approach across different content areas and cognitive skills in Biomolecules.

Table 13. *Summary Table for the "t-test" for the Students' Performance Before and After the FC-PjBL Hybrid Approach in Different Content Areas*

Section	Content Areas	$\underline{x}_{pre}$	$\underline{x}_{post}$	s^2_{pre}	s^2_{post}	df	*t*	Sig	Cohen's *d*
A	Carbohydrates	2.92	5.14	2.08	1.90	36	-7.70	.00*	1.57
	Lipids	2.92	5.05	1.85	1.39	36	-6.83	.00*	1.68
	Proteins	3.54	5.78	1.42	1.23	36	-9.87	.00*	1.95
	Nucleic Acids	2.46	4.92	1.26	1.47	36	-9.73	.00*	2.11
B	Carbohydrates	3.68	5.32	1.50	1.92	33	-9.23	.00*	1.26
	Lipids	3.00	5.06	1.94	1.45	33	-7.19	.00*	1.58
	Proteins	3.29	5.77	1.61	2.43	33	-9.86	.00*	1.74
	Nucleic Acids	2.59	5.00	2.55	1.64	33	-7.31	.00*	1.67
C	Carbohydrates	3.58	5.42	2.25	1.79	35	-6.29	.00*	1.29
	Lipids	3.19	5.08	1.82	1.22	35	-6.72	.00*	1.53
	Proteins	3.75	5.72	2.59	1.41	35	-8.20	.00*	1.39
	Nucleic Acids	2.72	4.94	2.09	1.48	35	-9.28	.00*	1.66

*$p < 0.05$ or 5% – *Significantly Different*
Large effect size according to Cohen's thresholds: ds ≥ 0.8.

The results (see Table 13) showed that the *p*-values in all sections and content areas are lower than the 5% significance level. The negative *t*-values also indicate the direction of improvement, with post-test scores exceeding pre-test scores. Therefore, the null hypothesis (H_o) is rejected in favor of the alternative hypothesis (H_a). Thus, there is a significant difference in students' content mastery across the different content areas in Biomolecules before and after the FC-PjBL hybrid approach was used. The Cohen's d value of all sections was above 0.8, Cohen's thresholds, indicating a large effect size of using the FC-PjBL hybrid approach. In sections A and C, the topic on nucleic acids had the largest effect size, with d = 2.11 and d = 1.66, respectively, while section B exhibited the highest effect size for proteins, with d = 1.74. Hence, the dependent-samples t-test and Cohen's d indicated that the FC-PjBL hybrid approach is highly effective in enhancing students' mastery of the different content areas in Biomolecules.

Table 14. *Summary Table for the "t-test" for the Students' Performance Before and After the FC-PjBL Hybrid Approach in Different Cognitive Skills*

Section	Cognitive Skills	$\underline{x}_{pre}$	$\underline{x}_{post}$	s^2_{pre}	s^2_{post}	df	*t*	Sig	Cohen's *d*
A	Knowledge	3.92	7.03	1.85	2.36	36	-10.84	.00*	2.14
	Comprehension	4.05	6.00	1.16	1.50	36	-7.25	.00*	1.69
	Application	2.57	4.95	1.70	1.50	36	-11.33	.00*	1.88
	Analysis	1.30	2.92	1.22	1.24	36	-8.00	.00*	1.46
B	Knowledge	4.74	7.24	3.47	3.34	33	-8.35	.00*	1.35
	Comprehension	3.65	5.88	1.99	2.29	33	-7.27	.00*	1.53
	Application	2.94	5.03	1.45	1.30	33	-7.79	.00*	1.78
	Analysis	1.24	3.00	0.79	1.27	33	-8.04	.00*	1.74
C	Knowledge	4.69	7.33	1.76	2.40	35	-9.65	.00*	1.83
	Comprehension	3.94	6.14	2.68	1.49	35	-8.14	.00*	1.52
	Application	3.00	4.69	2.17	1.42	35	-8.21	.00*	1.26
	Analysis	1.61	3.00	1.16	0.91	35	-5.87	.00*	1.36

*$p < 0.05$ or 5% – *Significantly Different*
Large effect size according to Cohen's thresholds: ds ≥ 0.8.

The results (see Table 14) showed that the *p*-values in all sections of different cognitive skills - knowledge, comprehension, application, and analysis are lower than the 5% significance level. The negative t-values also confirm that post-test scores across all sections exceeded pre-test scores. Therefore, the null hypothesis (H_o) is rejected in favor of the alternative hypothesis (H_a). Thus, there is a significant difference in students' cognitive skills performance across the different content areas in Biomolecules before and after the FC-PjBL hybrid approach was used. The Cohen's d value of all sections was above 0.8, Cohen's thresholds, indicating a large effect size of using the FC-PjBL hybrid approach. In section A, the knowledge and application levels have the largest effect size

observed with d = 2.14 and s = 1.88, respectively. In section B, the application and analysis levels showed substantial improvements with d = 1.78 and d = 1.74, respectively. In contrast, section C exhibited the largest effect sizes in knowledge, comprehension, and application, with d = 1.83, 1.52, and 1.26, respectively. The dependent-samples t-test and Cohen's d revealed that the FC-PjBL hybrid approach is practical in developing foundational learning, such as knowledge and comprehension, and higher-order thinking skills, such as application and analysis.

3.4 Experiences of Students in the Use of Flipped Classroom – Project-Based Learning (FC-PjBL) Hybrid Approach in Biomolecules

The students' narrative statements highlight insights, challenges faced, and benefits gained, providing a qualitative perspective on the effectiveness of the FC-PjBL Hybrid Approach in the teaching and learning process. Table 15 presents the themes of students' experiences with the Flipped Classroom-Project-Based Learning (FC-PjBL) Hybrid Approach in Biomolecules.

Table 15. *Themes on the Students' Experiences in the Use of the Flipped Classroom – Project-Based Learning (FC-PjBL) Hybrid Approach*

Theme Clusters	Emergent Themes
Teacher-Guided Learning Constructive Feedback Resolution of Problems	Teacher's Role in Constructive Learning
Simplified Learning Accessible and Repeatable Learning Simplified Learning and Independent Learning Independent Learning Distractions in Learning Preference over the Traditional Approach	Streamlined Learning
Concept Clarification Confidence and Self-Assurance Reflection and Insights Motivators of Learning	Empowered Learning and Self-Reflection
Preparation for Active Learning Active Engagement in Learning Hands-on Experience Skill Development Preference over the Traditional Approach	Active and Experiential Learning
Recalling Information Application of Learning Experience In-Depth Understanding Project's Relevance	From Knowledge to Application
Skill Development Collaboration and Support Challenges in Learning	21st Century Skills in Action

The results (see Table 15) showed that the themes derived from the students' experience revealed a multifaceted impact of the Flipped Classroom-Project-Based Learning (FC-PjBL) Hybrid Approach, such as the Teacher's Role in Constructive Learning, Streamlined Learning, Empowered Learning, Self-Reflection, Active and Experiential Learning, From Knowledge to Application, and 21st Century Skills in Action. As shown, the hybrid approach was perceived by students as beneficial for improving academic performance and personal growth.

Theme 1: Teacher's Role in Constructive Learning

In the teacher's role in constructive learning, students emphasized that the teacher's implementation of the FC-PjBL hybrid approach is important for deepening understanding of the lesson, as the teacher provides clear instructions and facilitates meaningful discussion during in-class sessions. Lines stated during the focus group discussion were:

P-08: "*If the teacher gives actual instruction, we can easily absorb the content*".

In addition, the teacher's role helps foster a sense of security and aids students in mastering the content. Regular teacher feedback, especially during project development, helps students strengthen areas that need improvement, which is essential for growth. Lines stated during the focus group discussion were:

P-02: "*The target population should easily understand our project.*"
P-05: "*The approach used by the teacher-demonstrator pushes us to finish the project. If the teacher did not use that approach, the project would not be finished on time.*"

According to Romzek (2024), the role of the teacher is to guide students in navigating challenges and exploring solutions, and to support them when they struggle. The idea of project-based learning is to create authentic learning experiences for students. Also, the pillars of flipped learning emphasize that, although the teacher's role is less visibly prominent in the flipped classroom, it remains the essential ingredient for the approach to succeed (Flipped Learning Network, 2014). Hence, the students' experiences highlight the teacher's critical role in implementing the FC-PjBL hybrid approach.

Theme 2: Streamlined Learning
In implementing the FC-PjBL hybrid approach, students experienced a more streamlined learning experience. During the implementation, the students appreciated how the FC-PjBL hybrid approach simplified complex topics and was able to break them into manageable parts, which enabled the students to take notes and learn the content on their own time, pace, and space, ensuring comprehension, and repeat the materials several times if the concept was unclear. Lines stated during the focus group discussion were:

P-09: "*For me, it was helpful. Especially the video presentation since the lesson was explained through video, and students will be able to rewatch it again.*"

The students emphasized that the approach promoted autonomy in learning, allowing them to explore topics independently and use materials beyond the prepared ones. However, despite its advantages, some students reported challenges, specifically in independent learning and in using social media as a primary distractor in completing the assignment. Lines stated during the focus group discussion were:

P-06: "*I did not finish watching the video lessons because I was enticed to open my Facebook account.*"

Still, students preferred the FC-PjBL hybrid approach over the traditional method, as it allowed them to engage and deepen their understanding of the topics actively. According to Cambridge University (n.d.), streamlining improves the effectiveness of an organization, such as a business or government, by simplifying its activities. In the context of education, streamlined learning is making learning inside or outside the classroom simpler, allowing students to learn the content in their own time, space, and pace, take notes, and review the materials as many times as needed, ensuring maximum comprehension. Streamlined education can help learners explore other materials, developing a sense of autonomy. According to Fotiadou et al. (2017), learner autonomy is one factor that can affect students' learning processes in distance learning and is linked to traits that urge students to take responsibility for their learning. Aldosari and Alsager's (2023) study revealed that students' performance increased directly with learning autonomy, in which pupils are actively involved in the learning process, and that learning autonomy had the most significant impact on their ability to evaluate their performance. The students' experiences highlight the importance of a streamlined, learner-autonomous approach to implementing the FC-PjBL hybrid approach.

Theme 3: Empowered Learning and Self-Reflection
In empowered learning and self-reflection, the students accentuated that the FC-PjBL hybrid approach encourages them to have self-assessment and reflection on their learning progress, develop confidence and self-assurance of their learning from the materials they consumed before class, have an opportunity for introspection in which enables them to connect their knowledge to real-world contexts specifically the diseases associated with biomolecules as a result of project development and presentation, and provide them intrinsic and extrinsic motivators to engage and positively reinforced the projects triggering their enthusiasm and interest. Lines stated during the focus group discussion were:

P-01: "*Our booth is all about awareness of genetic disorders. Through this, the target population can change their mind that having a genetic abnormality does not mean they are not human. They are special, and we need to treat them fairly and equally.*"

According to Titus and Muttungal (2023), empowered learners exhibit high motivation, a sense of obligation, self-efficacy, and the ability to make sound decisions. In the context of the FC-PjBL hybrid approach, the students experienced learning empowerment, as learning the content before conducting in-class activities increased their confidence and self-assurance that they could answer questions in different activities. A sense of commitment and ability to make the right decision is also another offshoot of the implementation of the FC-PjBL hybrid approach, in which students can propose projects that are deemed important not only to a specific population but also covering an entire community, and are also able to do introspection of the learning that they gained throughout the process. According to Edmentum (2023), self-reflection is an important part of learning that allows learners to evaluate their progress and understanding. In Cavilla's (2017) study, there is a positive correlation between student reflection and academic performance and motivation. In addition, enhanced metacognition occurred at both intellectual and affective levels among students who engaged in self-reflection (Cavilla, 2017). Hence, the students' experiences highlight that empowered learning and self-reflection were important tenets of the FC-PjBL hybrid approach.

Theme 4: Active and Experiential Learning

In active and experiential learning, the students experienced the hands-on nature of the activities, such as the laboratory activities or experiments, the conduct of group activities and class discussions through collaboration among peers, and opportunities to develop a project applying what the students learned from the class, such as video materials and pamphlets, making the FC-PjBL hybrid approach preferred by the students.

P-01: "*I prefer the hands-on activity because I can learn more*".
P-07: "*The hands-on activities help me to learn and focus on the subject.*"

According to Bartle (2015), experiential learning is defined as 'learning by doing' in which the students are actively engaged in the educational process through inquiry, reflection, analysis, and synthesis. Using the FC-PjBL hybrid approach, students engaged in experiential learning, particularly during laboratory activities in which they conducted inquiries, analyzed results, and synthesized research findings to develop projects for the target population. The review conducted by Kong (2021) revealed that experiential learning encouraged learners to think logically, find solutions, and take appropriate action in relevant situations. However, it was also revealed that students find it challenging and time-consuming because they must work in groups during hands-on activities (Kong, 2021). The students' experiences with the FC-PJBL hybrid approach were comparable to the experiential learning review's findings. However, even with these challenges, experiential learning pedagogies showed a positive overall impact on academic achievement among children aged 4–14, as evidenced by a systematic review (Ranken et al., 2024). Hence, students' experiences highlight that the FC-PjBL hybrid approach encourages active, experiential learning.

Theme 5: From Knowledge to Application

For the theme from knowledge to application, the students experienced, during the implementation of the FC-PjBL hybrid approach, a transition from recalling information to applying their learning experiences, ensuring deeper comprehension of the topic of biomolecules. The students emphasized that through this hybrid approach, they can apply the lesson to themselves and the community, relate the topic to real-world contexts, explore the deeper aspects of the lesson, and engage in self-reflection on their learning, leading to value formation. The students emphasized that in-class activities, such as laboratory work and projects, could connect their theoretical concepts to practical scenarios, thereby increasing their interest and motivation. By applying the learning experience through project development, the students were able to complete the projects, reinforcing their understanding and retention of the subject matter, even amid challenges such as resource and time constraints and teamwork.

P-09: "*In our physical aspect, I am now aware of the food we eat, the diet, and how to avoid having chronic diseases.*"
P-10: "*I am working for my Chief Girl Scout Award. I think the lessons from this class, as illustrated in the pictures, help me understand how to address malnutrition among children. I will conduct my outreach in the limestone area where students there have big stomachs and need immediate medical attention.*"

According to Somaa (2024), the flipped classroom approach significantly enhances students' academic achievement and accommodates diverse cognitive styles. In addition, the study by Ma (2023) revealed that the flipped classroom approach enhanced students' critical thinking and led to better assessment results, greater understanding of the theories, and greater ability to apply them to real-world situations. On the other hand, Project-Based Learning (PjBL) encourages learners to explore multifaceted problems. It supports the mastery of complex knowledge and practical problem-solving skills that cultivate creative thinking (Yu, 2024). Hence, hybridizing these two approaches creates a synergistic effect in improving students' cognitive skills, from recalling information to applying theories in real-world contexts, based on students' standpoints and performance levels.

Theme 6: 21st Century Skills in Action

In the 21st Century Skills in Action, the students demonstrated diverse skill sets in implementing the FC-PjBL hybrid approach, including resourcefulness, creativity, time management, collaboration, problem-solving, communication, decision-making, and the integration of ICT in the development and improvement of projects.

P-04: "*I gained from the project the collaboration, creativity, and time management*".
P-05: "*I developed my communication and problem-solving skills in addressing minor problems in the project.*
P-06: "*I developed my public speaking skills.*"

According to Binkley et al. (2011), twenty-first-century skills are abilities and attributes that students can learn to enhance their thinking, learning, working, and living in this world. In addition, the 21st-century skills include creativity and innovation, critical thinking, problem-solving and decision-making, metacognition, communication, collaboration, ICT literacy, citizenship (global and local), life and career skills, and personal and social responsibility (Binkley et al., 2011). According to Kennedy (2024), in the present, where AI and rapid technological progress dominate, the contemporary workplace requires individuals equipped with higher-order cognitive abilities; hence, educators should instill 21st-century skills in students through a relevant curriculum. Henceforth, the use of the FC-PjBL hybrid approach enables students to develop 21st-century skills that adapt to the changing demands of the environment.

3.5 Joint Display Analysis of Data of Quantitative and Qualitative Findings Across Related Themes in the Use of FC-PjBL Hybrid Approach

The result of the Joint Display Analysis on the effectiveness of the Flipped Classroom-Project-Based Learning (FC-PjBL) Hybrid Approach, the integration revealed three emergent themes: "Enhanced Mastery through Simplified, Empowered, and Reflective Learning", "Constructive Scaffolding for Enhanced Content Mastery", and "Improved Cognitive Skills through Active, Experiential, and 21st Century Skills-Based Learning".

In the quantitative part, the data revealed significant improvements in students' performance across the different content areas and cognitive skills in Biomolecules, as indicated by the mean scores, N-gain index, and a dependent-samples *t*-test of the pre-test and post-test scores. In the qualitative part, the data also revealed the themes that are pivotal in the enhanced content mastery, such as Streamlined Learning, Empowered Learning, Self-Reflection, the Teacher's Role in Constructive Learning, and the improvement of cognitive skills, such as Active and Experiential Learning, From Knowledge to Application, and 21st Century Skills in Action. These factors highlight the FC-PjBL Hybrid Approach's ability to develop cognitive and life skills, ensuring holistic growth among students. Table 16 presents the joint display analysis of quantitative (content mastery) and qualitative findings across related themes using the FC-PjBL hybrid approach.

In the data integration (see Table 16), the relationship between the quantitative and qualitative findings revealed a connecting-merging pattern in which students' content mastery aligned with their experiences. This alignment between the quantitative and qualitative findings underscores that the FC-PjBL hybrid approach is effective in enhancing content mastery by fostering simplified, empowered, and reflective learning. The teacher's scaffolding plays a critical role in the effectiveness of the hybrid methodology, leading to a deeper understanding of the content and enhanced mastery. According to Bolivar et al. (2023), a hybrid methodology combining project-based learning (PjBL) and a flipped classroom (FC) yields significant benefits, resulting in more effective learning and positive student comments and support compared to the traditional approach. Furthermore, Unugo (2021) highlighted that the scaffolding strategy (SCS) affects students' academic achievement. By combining constructive scaffolding with the hybrid methodology, this approach fosters better learning among students.

Table 16. *Joint Display Analysis of Quantitative (Content Mastery) and Qualitative Findings Across Related Themes in the Use of FC-PjBL Hybrid Approach*

Quantitative Findings		Emerging Theme	Qualitative Findings	
Data	**Categories**		**Categories**	**Codes**
Content Mastery **Carbohydrates** From "Moderately Mastered" (48.47%) to "Highly Mastered" (75.60%), with a "Moderate Gain" (*N*-gain: 0.48). **Dependent Sample *t*-Test**: Significant improvement in all sections with pre-test means ranging from 2.92 to 3.68 and post-test means from 5.14 to 5.42 (p = 0.00). **Lipids** From "Moderately Mastered" (43.40%) to "Highly Mastered" (72.36%), with a "Moderate Gain" (*N*-gain: 0.45). **Dependent Sample *t*-Test**: Significant improvement in all sections with pre-test means ranging from 2.92 to 3.19 and post-test means from 5.05 to 5.08 (p = 0.00). **Proteins** From "Less Mastered" (39.20%) to "Moderately Mastered" (63.96%), with a "Moderate Gain" (*N*-gain: 0.39). **Dependent Sample *t*-Test**: Significant improvement in all sections with pre-test means ranging from 3.29 to 3.75 and post-test means from 5.72 to 5.78 (p = 0.00). **Nucleic Acids** From "Less Mastered" (37.00%) to "Highly Mastered" (70.77%), with a "Moderate Gain" (*N*-gain: 0.50). **Dependent Sample *t*-Test**: Significant improvement in all sections with pre-test means ranging from 2.46 to 2.72 and post-test means from 4.92 to 5.00 (p = 0.00).	The use of the FC-PjBL Hybrid Approach improved students' content mastery, as evidenced by pre-test vs. post-test scores. *N*-gain and dependent sample *t*-test results of the students in all sections in different content areas in Biomolecules: Carbohydrates, Lipids, Proteins, and Nucleic Acids.	Enhanced Mastery Through Simplified, Empowered, and Reflective Learning	Streamlined Learning	The use of the FC-PjBL Hybrid Approach simplified the learning experience. Students can learn at their own pace, access the materials easily, and review them as often as needed.
			Empowered Learning and Self-Reflection	FC-PjBL Hybrid Approach empowered learners to gain confidence and autonomy in their learning. FC-PjBL Hybrid Approach encourages self-assessment and reflection.
		Constructive Scaffolding for Enhanced Content Mastery	Teacher's Role in Constructive Learning	The teacher's role is essential for a deeper understanding of the lessons. The teacher's feedback helps in understanding the lessons and the project's accomplishment.

Table 17. *Joint Display Analysis of Quantitative (Cognitive Skills) and Qualitative Findings Across Related Themes in the Use of FC-PjBL Hybrid Approach*

Quantitative Findings		Emerging Theme	Qualitative Findings	
Data	**Categories**		**Categories**	**Codes**
Cognitive Skills **Knowledge** From "Moderately Mastered" (44.49%) to "Highly Mastered" (71.98%), with a "Moderate Gain" (*N*-gain: 0.48). **Dependent Sample *t*-test**: Significant improvement in all sections with pre-test means ranging from 3.92 to 4.74 and post-test means from 7.03 to 7.33 (p = 0.00). **Comprehension** From "Moderately Mastered" (43.12%) to "Moderately Mastered" (66.75%), with a "Moderate Gain" (*N*-gain: 0.38). **Dependent Sample *t*-test**: Significant improvement in all sections with pre-test means ranging from 3.65 to 4.05 and post-test means from 5.88 to 6.14 (p = 0.00). **Application** From "Moderately Mastered" (40.52%) to "Highly Mastered" (69.86%), with a "Moderate Gain" (*N*-gain: 0.48). **Dependent Sample *t*-test**: Significant improvement in all sections with pre-test means ranging from 2.57 to 3.00 and post-test means from 4.69 to 5.03 (p = 0.00). **Analysis** From "Less Mastered" (34.53%) to "Highly Mastered" (74.32%), with a "Moderate Gain" (*N*-gain: 0.56). **Dependent Sample *t*-test**: Significant improvement in all sections with pre-test means ranging from 1.24 to 1.61 and post-test means from 2.92 to 3.00 (p = 0.00).	The use of the FC-PjBL Hybrid Approach improved students' cognitive skills, as evidenced by pre-test vs. post-test scores. *N*-gain and dependent sample *t*-test results of the students in all sections in different content areas in Biomolecules: Carbohydrates, Lipids, Proteins, and Nucleic Acids.	Improved Cognitive Skills Through Active, Experiential, and 21st-Century Skills-Based Learning	Active and Experiential Learning From Knowledge to Application 21st Century Skills in Action	The use of the FC-PjBL Hybrid Approach promotes active learning and hands-on experience. Students easily recall information, apply it to learn, and have an in-depth understanding of real-world context. FC-PjBL Hybrid promotes skill development such as communication, collaboration, creativity, decision-making, leadership, problem-solving, resourcefulness, and time management.

The joint display analysis of cognitive skills (see Table 17) alongside students' experiences highlights students' ability to recall, understand, apply, and analyze concepts in Biomolecules. The analysis of cognitive skills also highlights whether the FC-PjBL hybrid approach promotes higher-order thinking skills (HOTS), an essential component of 21st-century Learning. The relationship between the quantitative and qualitative findings revealed a pattern of connection and merging in which the students' cognitive skills aligned with their experiences. This alignment between the quantitative and qualitative findings underscores that the FC-PjBL hybrid approach is practical in improving students' cognitive skills by promoting active, experiential learning during in-class sessions and project development and presentation, with particular emphasis on the development of 21st-century skills.

According to Listiqowati et al. (2021), the use of a project-based flipped classroom (PjBFC) model has a significant effect on the development of critical thinking skills. The study by Listiqowati et al. (2021) also aligned with the study by Sholahuddin et al. (2023), which found that students in classes that used the project-based learning flipped classroom (PjBL-FC) performed better than those in classes that used the project-based learning model (PjBL) alone. Scientific literacy and critical thinking are important components of any science education. According to Lestari and Setyarsih (2021), scientific literacy skills are supported by critical thinking, and scientifically literate students will be able to think critically about problems. Hybridizing the flipped classroom approach and project-based learning promotes scientific literacy and critical thinking skills, as they directly relate to students' cognitive skills, such as remembering, understanding, applying, and analyzing scientific knowledge.

3.6 A Pedagogical Model for Science Education in Teaching Biomolecules Using the FC-PjBL Hybrid Approach

Introduction

To achieve higher performance levels in content mastery and cognitive skills in General Biology, students need a deeper understanding of the subject matter, including its application to themselves and their community, beyond theoretical knowledge. However, teachers faced challenges in implementing various teaching approaches, including limited resources, insufficient training in delivering the approaches, time constraints, and perceived benefits. Hence, teachers resort to traditional teaching methods that fail to address students' poor critical thinking, limited skill acquisition, low scientific literacy, and poor application of scientific concepts in everyday life. This is evident with the existing results of various international assessments conducted by PISA, TIMSS, and SEA-PLMS. The World Bank highlighted the "medium-low" level of effective teaching practices among Filipino teachers as another challenge. This limitation underscores the need for a more dynamic, student-centered approach to teaching General Biology. The Flipped Classroom – Project-Based Learning (FC-PjBL) Hybrid Approach offers a solution to addressing the limitations of the conventional approach. This approach provides students with an opportunity to learn the content more deeply while developing critical cognitive skills, such as application and analysis. This hybrid approach promotes reflective learning, in which students engage in introspection and consider how it affects them and the community. With the evolving need for a practical approach to teaching in the changing landscape of education and the demands of 21st-century teaching, science teachers need a broad repertoire of skills to adapt. Hence, this study designed a pedagogical model for teaching Biomolecules in General Biology using the FC-PjBL Hybrid Approach to enhance content mastery and improve students' cognitive skills.

Rationale

This model was derived from the actual evaluation of students' performance levels in content mastery and cognitive skills across the different content areas in Biomolecules, and from the 108 Science, Technology, Engineering, and Mathematics (STEM) strand students in a public national high school in Polomolok, South Cotabato. To support the evaluation results, an FGD was conducted with students about their experiences under the flipped–classroom–project–based (FC-PjBL) Hybrid Approach. The findings from the evaluation of the student's performance in terms of content mastery (carbohydrates, lipids, proteins, and nucleic acids) and cognitive skills (knowledge, comprehension, application, and analysis) and the result of the Focus Group Discussion were used in designing the pedagogical model for teaching Biomolecules in General Biology using the Flipped Classroom-Project-Based Learning (FC-PjBL) Hybrid Approach. It aimed to enhance content mastery and improve students' cognitive skills in teaching General Biology.

Goals and Objectives

The goal of the model is to enhance students' content mastery and cognitive skills in the Biomolecules of Science, Technology, Engineering, and Mathematics program at a public national high school in Polomolok, South Cotabato. To achieve this, the designed model comprises six components anchored to the core, with lines indicating their interrelationships. The components are streamlined learning, empowered learning, reflective

learning, constructive scaffolding, active and experiential learning, and 21st-century skills-based learning. Hence, if the teacher implements the FC-PjBL Hybrid Approach in teaching different content in Biomolecules, students' performance will improve in both content and cognitive skills.

Guiding Principles

The findings from the students' evaluation, Focus Group Discussion (FGD), and Joint Display Analysis (JDA) resulted in a proposal for a pedagogical model for teaching Biomolecules in General Biology. The proposed pedagogical model is based on the following principles: student-centered learning, constructivist approach, technological integration, inquiry-based learning, active learning, collaboration and communication, and reflection and metacognition.

Framework of Flipped Classroom–Project-Based Learning (FC-PjBL) Hybrid Approach Pedagogical Model

In the pedagogical model illustrated in Figure 2, the central focus is Enhanced Content Mastery and Cognitive Skills. The goal of the Flipped Classroom – Project-Based Learning (FC-PjBL) Hybrid Approach is to achieve a deep understanding of the topics while the higher-order thinking skills (HOTS) are developing. In the pedagogical model, the central focus is supported by the six interconnected components that emphasize the holistic approach to learning. These are streamlined learning, empowered learning, reflective learning, constructive scaffolding, active and experiential learning, and 21st-century-based learning. The interconnected components result from integrating quantitative and qualitative findings through the Joint Display Analysis. Figure 2 presents the FC-PjBL Hybrid Approach Pedagogical Model.

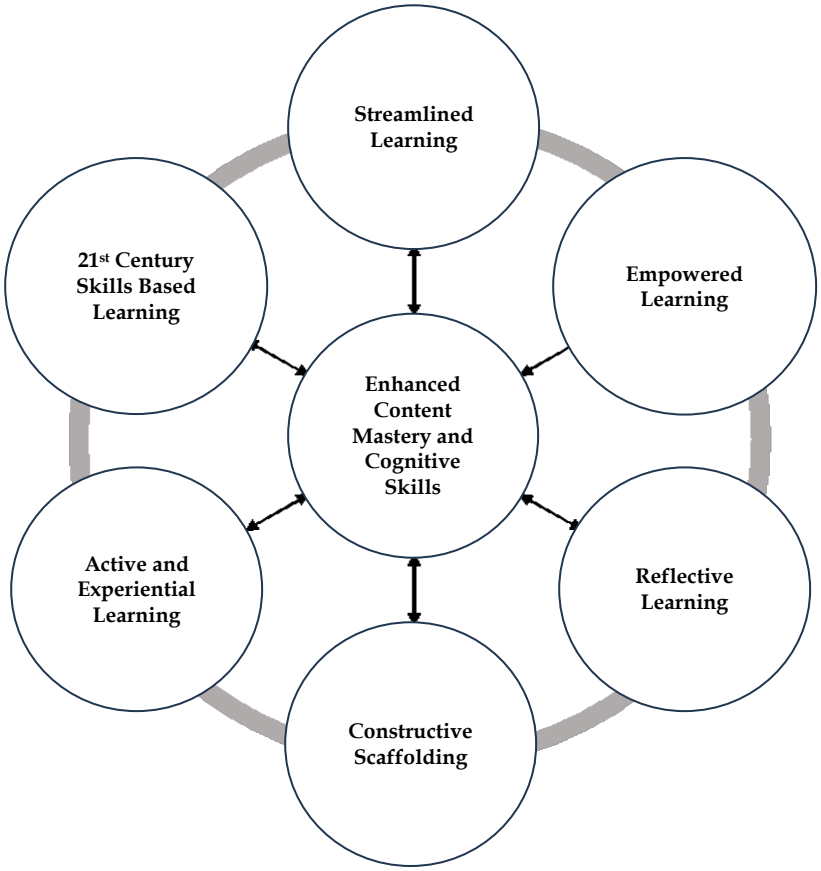

Figure 2. *FC-PjBL Hybrid Approach Pedagogical Model (Plecis, 2025)*

In streamlined learning, the focus is on simplifying content delivery through the flipped classroom approach (FCA), in which learning materials, such as video lessons, are consumed before class on their own time, space, and pace. In addition, students can access and repeat the materials, breaking them into simpler parts for better understanding, thereby developing autonomy and responsibility for their learning experience. Other components of the model are empowered learning and reflective learning, through the use of the Flipped Classroom – Project-

Based Learning (FC-PjBL) Hybrid Approach the students are encouraged to gain confidence and self-assurance of the concept they learned before the in-class session, clarify their understanding, and able to do an introspection of their learning or tasks (project-based tasks) towards self and to the community. Through empowered learning, the students are encouraged to take ownership of their learning and make decisions in project development that provide solutions to the target population.

In addition, through reflective learning, students can engage in self-assessment and reflect on what they have learned throughout the process. They can form values, which are essential to holistic development. Another component is constructive scaffolding, in which the teacher plays a critical role in the implementation of the Flipped Classroom – Project-Based Learning (FC-PjBL) Hybrid Approach, in which the teacher's role is to facilitate the in-class activities, provide feedback on the students' projects, and find a resolution to the problems that arise during the development. The role of the teacher is essential in the project development phase of the hybrid approach, where feedback helps achieve the project's objectives.

Another component of the model is active and experiential learning. The use of the Flipped Classroom – Project-Based Learning (FC-PjBL) Hybrid Approach promotes hands-on experiences and practical activities to link theoretical knowledge learned before and during in-class sessions. Through hands-on activities, students can improve their higher-order thinking skills (HOTS) and deepen their mastery of the subject matter. Lastly, the 21st Century Skills-Based Learning, through the use of the Flipped Classroom – Project-Based Learning (FC-PjBL) Hybrid Approach, supports skills development, which is part of 21st Century Learning. It helps develop essential skills such as collaboration, communication, critical thinking, problem-solving, and creativity, thereby enhancing content mastery and cognitive development.

In the model's interconnectivity, each component is essential to enhancing students' content mastery and cognitive skills. In the simplification of content delivery (streamlined learning) through the Flipped Classroom Approach (FCA), the time allotment for the subject is now focused on developing 21st-century skills. Hence, more time and space are devoted to deepening the lessons, such as conducting laboratory activities and collaborating on project development. In empowering learning and reflective learning, students are encouraged to take ownership of their learning, leading to self-assessment of their progress and the decisions they make. Even if students are given autonomy in their learning and the opportunity to self-assess, the teacher's role in providing constructive feedback is critical, especially in guiding students to succeed, such as by developing projects that are Specific, Measurable, Achievable, Relevant, and Time-Bound (SMART). Through constructive scaffolding, students also gain the knowledge and skills needed to accomplish hands-on activities, especially the more complex and challenging ones (active and experiential learning).

In the interconnectivity between active and experiential learning and 21st-century skills-based Learning, hands-on and practical activities, such as laboratory activities, project development, or presentations, help develop skills such as collaboration, communication, critical thinking, problem-solving, and creativity. Moreover, streamlined learning helps students reduce cognitive load by breaking materials into manageable parts, exploring related materials, and allowing flexibility in their learning process, leading to empowered learning. From reflective to active and experiential learning, students' experiences in hands-on activities and project development or presentation solidify their learning, fostering meaningful experiences such as recognizing the impact of the food they eat on their bodies and making healthier choices. The interconnectivity between streamlined learning and constructive scaffolding is enhanced when content is delivered in a simplified manner, reducing the teacher's burden during lesson preparation. Hence, leads to more time for giving constructive feedback on the student's progress and assisting students who have difficulty with the lessons. In the context of empowered learning and 21st-century skills-based Learning, an empowered learner can practice these skills through project development and presentation in real-world contexts, leading to meaningful outcomes. Hence, the interconnectedness of the six components in this pedagogical model ensures that the students not only master the content (cognitive domain) but also develop their skills (psychomotor domain) and imbibe values (affective domain), leading to holistic development.

4.0 Conclusion

This study examined whether the Flipped Classroom–Project-Based Learning (FC-PjBL) Hybrid Approach could enhance students' content mastery and cognitive skills in Biomolecules, particularly in carbohydrates, lipids, proteins, and nucleic acids. The use of a Flipped Classroom-Project-Based Learning (FC-PjBL) Hybrid

Approach is effective in enhancing students' content mastery in Biomolecules (carbohydrates, lipids, proteins, and nucleic acids). Before implementing the FC-PjBL hybrid approach, some areas were less well understood, such as proteins and nucleic acids. After implementing the FC-PjBL hybrid approach, it showed improvement, highlighting that this approach addresses learning gaps among students. In the cognitive skills, the data suggest that there was an improvement in the cognitive skills (knowledge, comprehension, application, and analysis) among students before and after the Flipped Classroom-Project-Based Learning (FC-PjBL) Hybrid Approach was used in different content areas in Biomolecules. Before implementing the FC-PjBL hybrid approach, some skills were less well mastered, particularly knowledge, application, and analysis. The implementation of the FC-PjBL hybrid approach improved knowledge, application, and analysis, but comprehension remained in the same category, even with a significant increase before and after the implementation. The planned activities for this approach might not have aligned with the demand to boost students' comprehension. Hence, there is a need to make instructional adjustments. The analysis of the two population means indicates a significant difference in students' performance before and after using the FC-PjBL hybrid approach across the different content areas and cognitive skills in Biomolecules. This means that the FC-PjBL hybrid approach enhanced the students' mastery and improved their cognitive skills. It is recommended that a longitudinal study be conducted to assess the effectiveness of the FC-PjBL hybrid approach on students' content mastery and cognitive skills.

The qualitative findings suggest that the FC-PjBL hybrid approach positively influenced students through teacher-constructed feedback, a simplified learning experience, active engagement in hands-on activities, self-reflection, and the development of 21st-century skills. However, instructional adjustments are needed to further assist students in linking theory to practice, specifically in areas that need improvement. Nevertheless, the FC-PjBL hybrid approach enhances students' higher-order thinking skills. As a result, the students experienced the benefits of the FC-PjBL hybrid approach, including the teacher's role in constructive learning, streamlined learning, empowered learning, introspection, active and experiential learning, the application of knowledge, and the development of 21st-century skills. It is recommended that future research explore the students' and teachers' experiences in longitudinal qualitative studies or case studies to enrich understanding of the effectiveness of the FC-PjBL hybrid approach in both teaching and student learning processes.

The integration of the qualitative and quantitative findings revealed that the FC-PjBL hybrid approach enhanced students' content mastery and cognitive skills across the different content areas in Biomolecules through simplified, empowered, reflective, active, experiential, and 21st-century Skills-Based Learning. However, the data suggest that the FC-PjBL hybrid approach improved content mastery and higher-order thinking skills, but that refining the tasks and providing more scaffolding are necessary. The use of the FC-PjBL Hybrid Approach enhanced the performance of General Biology students in Biomolecules across content areas and cognitive skills, while fostering simplified, empowering, reflective, and constructive feedback and experiential learning, thereby promoting the development of 21st-century skills. It is recommended that teacher training, collaborative expertise sessions (CES), or division-wide training for teachers be implemented to support the implementation and management of flipped classrooms and the facilitation of project-based learning.

With this in mind, the FC-PjBL Hybrid Approach Pedagogical Model was designed to address the teaching and learning needs of General Biology students. Based on the study's findings, the use of the FC-PjBL Hybrid Approach Pedagogical Model to address students' low performance in Content Mastery and Cognitive Skills aims to improve students' learning and experiences.

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The authors indicate equal contribution to each section. The authors reviewed and approved the final work.

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