JPII 14 (3) (2025) 563-584

Jurnal Pendidikan IPA Indonesia

https://journal.unnes.ac.id/journals/jpii

INTEGRATING EAST NUSA TENGGARA'S LOCAL WISDOM INTO PROJECT-BASED LEARNING TO ASSESS STUDENTS' CONCEPT COMPREHENSION, CRUCIAL LEARNING SKILLS, AND ATTITUDES TOWARDS CHEMISTRY LEARNING

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DOI: 10.15294/jpii.v14i3.20523

Accepted: January 23rd, 2025. Approved: September 26th, 2025. Published: September 26th 2025

ABSTRACT

This research aims to analyze the strategies employed in the implementation of Chem-PjBL-L-NTT-W (the Integration of NTT local wisdom in PjBL for chemistry), their effects on crucial learning skills (CLS), attitudes toward chemistry learning (ATCL), and comprehension of concepts. An investigation into students' perspectives and the difficulties encountered by teachers during implementation has been undertaken. A quantitative and qualitative research study with a one-group pretest-posttest design was employed. Paired t-test and Wilcoxon signed-rank test were used based on the normality of the data obtained by the Kolmogorov-Smirnov test. The results showed that the implementation strategy of the Chem-PjBL-L-NTT-W model was carried out through the identification and integration of the characteristics of chemistry materials with NTT local wisdom, along with the determination of three project themes for each learning material. The implementation of this model has a significant effect on CLS and ATCL, with variations in effects based on the school context. The effect on CLS was strong for senior high school students in the TTS regency, moderate in the Belu regency, and statistically significant but with a very small effect in the TTU regency. Regarding the ATCL aspect, there was a significant and strong effect in TTS, but the practical improvement was relatively minimal. In contrast, in Belu, the effect was very small and inconsistent. Students' concept comprehension in all three regencies showed significant improvement, with a range of confidence intervals indicating meaningful practical effects. Geographical location, facility and infrastructure availability, teacher readiness, school policies, and student interest have been recognized as critical determinants.

Keywords: local wisdom; project-based learning; concept comprehension; crucial learning skills; attitudes

INTRODUCTION

Educational research should focus on elements that are consistently evident in the current curricular modifications in Indonesia. Furthermore, these elements require examination of their effectiveness in addressing educational challenges. The project-based learning (PjBL) model meets the requirements of the learning process standards and is implemented in several curricula in Indonesia (Wijayanto et al., 2017). The PjBL model is an effective pedagogical approach for imparting 21st-century skills, encompassing critical thinking, problem-solving, creativity, collaboration, communication, scientific literacy, and technological literacy (Amelia & Santoso, 2021; Zayyinah et al., 2022; Artama et al., 2023), which persist as a focal point in science education research.

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The quality of education in Nusa Tenggara Timur (East Nusa Tenggara), a province in Indonesia, still faces fundamental challenges in the context of 21st-century skills, particularly in basic literacy. This is supported by a report from the Badan Pusat Statistik Nusa Tenggara Timur (BPS NTT) in 2024 (BPS-Statistics_NTT_Province, 2025). This report lists the results of NTT's literacy rate among the ten regions with the lowest scores ranked nationally. When linked nationally, the PISA 2022 report shows that Indonesia's overall ranking remains at a low level in almost all aspects of basic literacy, despite an improvement of 5-6 positions compared to 2018 (Kemendikbudristek, 2023). These national conditions are particularly relevant to NTT, which often faces greater educational challenges in various aspects. In addition to basic literacy, the head of secondary education at the NTT provincial education office revealed that by 2024, the number of certified high school teachers will be 22% (around 5000 teachers out of a total of 18,000), and 2,585 certified teachers out of a total of 9,000 vocational high school teachers (Ombudsman RI, 2024). This indicates that the low quality of education in NTT is also attributed to the limited number of professional teachers, who are often characterized by their lack of certified status. Certification is a formal process that ensures an educator possesses the necessary qualifications and competencies to teach professionally (Cowan & Goldhaber, 2018).

Several studies have been conducted in several public and private high schools in NTT. Indicating that the chemistry teachers observed in these studies have not used learning models and approaches with minimum process standards correctly and adequately, including the PjBL model (Kurniati et al., 2024; Polli et al., 2022; Ramen et al., 2022). A comprehensive evaluation of learning outcomes in the relevant domains for student achievement has yet to be conducted. The evaluation solely addresses the domain of knowledge and has not yet assessed the domain of skills. Certain chemistry learning materials are not practiced. Several obstacles have been identified, including the lack of laboratory facilities, challenges in analyzing the properties of chemistry materials for application with the PjBL model, the inability to formulate project themes to assist students in developing projects on specific chemistry materials, and difficulties in creating assessment criteria for learning outcomes at the stages of the PjBL model. Babinčáková et al. (2023) assert that the application of the PjBL model necessitates the gradual execution of formative assessments during the learning process to measure students' competencies; however, this has not been optimally realized in practice. Teachers frequently encounter difficulties due to the time-consuming nature of the process and the necessity for comprehensive preparation.

The PjBL model, grounded in local wisdom, helps mitigate the limitations of inadequate laboratory facilities in schools by utilizing environmentally sustainable materials readily available in students' everyday lives (Retnowati et al., 2020). The integration of local wisdom into chemistry teaching yields two advantages. This renders chemical principles more pertinent and comprehensible as they are linked to the students' cultural contexts (Wahyudiati & Qurniati, 2023). This model supports the preservation of local customs and the development of students' character (Mashami et al., 2023). Furthermore, it has been demonstrated to improve students' engagement and learning outcomes, rendering it a significant pedagogical tool (Pamenang, 2021). Only one study was identified that investigates the local wisdom of NTT and its application in education, specifically the research titled "The Potential of NTT's Ikat Weaving as a Teaching Resource in Schools" (Istikomayanti et al., 2024). Research on the local wisdom of East Nusa Tenggara has been thoroughly examined across various disciplines, including economics (Agustarini et al., 2022), social sciences (Riana et al., 2022), electronics (Tena & Dwiandiyanta, 2023), and biological sciences (Nitti et al., 2022). Nonetheless, there is a lack of studies about the integration of East Nusa Tenggara's local wisdom with the PjBL model in high school chemistry education in Indonesia.

Local wisdom is a cultural characteristic that characterizes each group of people in a particular region. Thus, it should be considered a key aspect in developing a country's education system. By integrating local wisdom into the education process, it can directly create a learning space that is engaging, responsive, and fair for diverse social groups. Internationally, considering local wisdom in the education system has been widely practiced. Flint et al. (2021) have encouraged curriculum, teaching, and teacher education reforms. It is further revealed that the education system needs to accommodate the cultural richness of the whole community in the United States, thus providing an equitable experience for all students. This is encouraged through a focus on culturally sustainable pedagogy. This concept is emphasized by Paris (2021), who discusses culturally sustaining pedagogies and their implications for our futures. Ladson-Billings (2021) also shared culturally relevant pedagogy (CRP) that academics have implemented. They extended their work beyond literacy and social studies to include STEM fields such as CReST (Culturally

Relevant STEM), which focuses on chemistry and social collaboration by Ferri and White (2024), and exploration of CRP practices by chemistry teachers in various universities (Cooper & Voigt, 2024) as documentation that CRP has been useful in various contexts. Ethnochemistry has also been studied by Chibuye and Singh (2024) as a practice that Zambians have applied in the past and present to teach chemistry in an ethnically responsive manner. Ademola et al. (2023) also implemented a cultural and technological collaboration framework, known as the Culturo-Techno-Contextual Approach (CTCA), in chemistry learning. Gulya and Fehérvári (2024) conducted a systematic review related to the development of culturally responsive pedagogy competencies for prospective teachers. It was further found that CRP-related studies were predominantly implemented in the United States, and only a small number of courses incorporated this aspect as a long-term and comprehensive approach into their curriculum.

Meanwhile, studies related to the integration of culture or local wisdom in education in Indonesia are still scarce in an internationally discussed context. The most recent study, conducted by Martawijaya et al. (2025), examined the integration of the Pancasila student profile (P3) based on Makassar local wisdom through co-curricular activities to strengthen physics concepts. Previously, Sakti et al. (2024) have also qualitatively examined the potential of ethnopedagogy in revitalizing local wisdom in early childhood character education in Indonesia. The integration of NTT local wisdom has not been studied or published internationally, despite NTT having a variety of cultures and local wisdom that are highly relevant to be integrated into the learning process.

One of the research objectives is to enhance the chemistry learning process through the PjBL model, integrating local wisdom from NTT, henceforth referred to as the "Chemistry project-based learning model with local NTT wisdom (Chem-PjBL-L-NTT-W)" as an innovative approach. The researcher seeks to identify the attributes of diverse local wisdom from NTT, correlate them with the characteristics of high school chemistry content as per the current curriculum, formulate project themes, devise assessment criteria for each project phase, subsequently process them in accordance with the research development framework, and propose them to chemistry teachers for implementation in the learning process. This is considered essential to address the limitations encountered by teachers due to insufficient knowledge and time in formulating the steps of the process and evaluation methods inside the PjBL model. This may also serve as an initiative to acclimate teachers to the sustainable implementation of the PjBL paradigm rooted in local NTT wisdom. Teachers can become adept at identifying the attributes of the content and local wisdom to be utilized in the learning process. Furthermore, it may provide continuous assistance in implementing the PjBL model and evaluating it at each requisite phase (Babinčáková et al., 2023).

This research utilizes Chem-PjBL-L-NTT-W to investigate high school learning materials on hydrocarbons, electron configurations, and chemical equilibrium. The teaching module suggested by Kemendikbud Dirjen PAUD Dikdasmen (2020) serves as a guide for teachers in implementing the Merdeka Curriculum, with content presented in the form of knowledge aspects. The specific skills acquired through the implementation of the PjBL model remain unclear, as there are no established indicators, criteria, or assessment methods for each phase of the student projects.

Preliminary research has been conducted to assess the needs pertinent to this project. This preliminary study involves eight chemistry teachers and 137 students from five high schools located in the city and regencies of NTT, specifically Kupang, Sumba Barat Daya (SBD), Rote Ndao, Timur Tengah Selatan (TTS), and Timur Tengah Utara (TTU). The selection of teachers and students considers the convenience of data collection for the researcher and the geographical distribution of schools to ensure the identification of diverse local knowledge from each region. This research aims to collect data using survey methods regarding the perceptions, experiences, and obstacles faced by teachers and students in implementing the PjBL model and local wisdom in NTT. Semi-structured interviews with teachers have been conducted to gather information regarding the objectives of this study.

The analysis of the research data indicates that Chem-PjBL-L-NTT-W should be adopted, since it aligns with the PjBL model's phases rooted in local wisdom in NTT and includes criteria for process evaluation. This is crucial in addressing time limitations and the deficiency of teacher expertise, which indicates that not all chemistry materials are pertinent to local understanding (Tinenti et al., 2025). The project's implementation requires the active participation of students in gathering information (Kokotsaki et al., 2016) and exploring diverse references. Consequently, researchers must ensure that the students involved in the study are not impeded by internet access in this regard.

This study seeks to investigate the impact of the Chem-PjBL-L-NTT-W implementation on students' problem-solving abilities, comprehension of chemical concepts, crucial learning skills (CLS), and attitudes toward chemistry learning (ATCL). This research is based on the fact that chemistry learning in various high schools in NTT has not progressed to optimize these components. The research conducted clearly indicates that the chemistry education process in NTT predominantly relies on conventional methods, which fail to adhere to established learning standards due to numerous constraints (Riti et al., 2021; Kurniati et al., 2024; Polli et al., 2022; Ramen et al., 2022). Moreover, the results indicate that students' learning outcomes in chemistry are generally inadequate and do not meet the passing grade. This can provide a foundation for reassessing the pedagogical approaches or other elements that directly affect students' comprehension of chemistry ideas.

In chemistry learning, a procedure that cultivates problem-solving abilities as an integral component of conceptual comprehension is essential. Conceptual comprehension refers to students' capacity to perceive, absorb, and interrelate significant ideas or concepts in chemistry, enabling them to use this knowledge in diverse contexts (Zuliyanti & Novaliyosi, 2023). Students possess conceptual comprehension if they have strong CLS (Abubakar & Arshad, 2015). The CLS under investigation in this work pertains to significant elements that will be addressed with Chem-PjBL-L-NTT-W. These elements encompass collaborative abilities, information synthesis, autonomous learning, and analytical problem-solving skills (Tian et al., 2023). In addition to CLS, ATCL has a significant influence on students' comprehension of chemistry subjects. Students with a strong ATCL have a positive influence on their comprehension of chemistry concepts (Nieswandt, 2007; Penn & Ramnarain, 2019; Ross et al., 2020). The ATCL analyzed in the application of Chem-PjBL-L-NTT-W is intricately connected to enjoyment in theoretical and experimental chemistry courses, perceptions of evaluation in school chemistry classes, and behavioral inclinations towards learning chemistry. The questions developed from these characteristics are utilized directly and unaltered (Cheung, 2011).

Conceptual understanding is analyzed from cognitive and emotional/affective viewpoints. From a cognitive perspective, a concept serves to identify and/or represent both concrete and abstract entities in reality, necessitating an effective methodology for concept acquisition from diverse real-world viewpoints, which is the primary emphasis in the domain of conceptual knowledge representation and processing (Li et al., 2015). This research aims to demonstrate that the Chem-PjBL-L-NTT-W can function as an effective alternative for idea learning. Employing an effective methodology to teach chemistry ideas helps enhance cognitive flexibility (Deák, 2004), a crucial trait of students. Ionescu et al. (2024) suggest that cognitive flexibility is closely associated with particular task elements and is significantly influenced by the domain. The emotive dimension suggests that a robust and affirmative self-concept, along with a perception of success in chemistry education, significantly contributes to students' comprehension of chemistry subjects after learning (Nieswandt, 2007). Consequently, emotional and affective dimensions significantly influence attitudes and achievement in chemistry education. This project aims to implement Chem-PjBL-L-NTT-W to investigate conceptual knowledge of problem-solving abilities, essential learning skills, and students' attitudes towards chemistry education.

This study seeks to investigate the implementation of Chem-PjBL-L-NTT-W in enhancing students' conceptual comprehension, CLS, and ATCL, guided by the following research questions:

1. What strategies are employed to implement Chem-PjBL-L-NTT-W in enhancing students' conceptual comprehension, CLS, and ATCL?
2. Does the implementation of Chem-PjBL-L-NTT-W affect students' CLS?
3. Does the implementation of Chem-PjBL-L-NTT-W affect students' ATCL?
4. What is the students' conceptual comprehension when instructed using Chem-PjBL-L-NTT-W?
5. What problems do teachers encounter, and how do students perceive the implementation of Chem-PjBL-L-NTT-W?

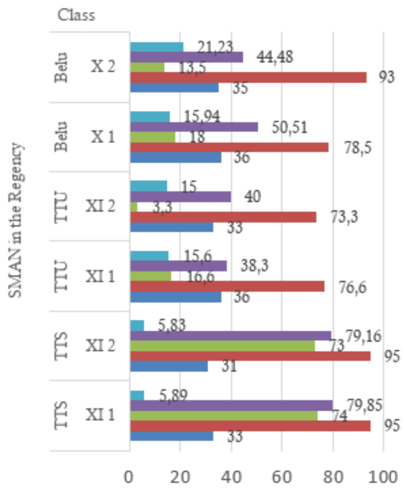
METHODS

This research was conducted in three public senior high schools located in three regencies in the NTT province of Indonesia during the odd semester (July to December 2024) of the 2024/2025 academic year. The three regencies are Timur Tengah Selatan (TTS), Timur Tengah Utara (TTU), and Belu.

A quasi-experimental research design with a one-group pretest-posttest methodology was employed. A control group was not used as teachers aimed to provide uniform treatment to all students.

The sample technique involved initially soliciting the consent of eight teachers who had been recruited and participated in the needs analysis phase. Three teachers indicated their readiness to implement the devised Chem-PjBL-L-NTT-W. They originate from TTS, TTU, and Belu. The group comprises two women and one male, each possessing over four years of teaching experience. The students they teach served as subjects in this investigation.

The researchers have secured authorization from the principal to enlist chemistry teachers and their students as participants in this study. The data collection approach in this study has received approval from the Institutional Review Board of the Research Ethics Committee of Universitas Negeri Malang (10.12.2/UN32.14/PB/2024, December 10, 2024). The development of the Chem-PjBL-L-NTT-W phases commences with the identification of chemistry learning materials to be presented by the teachers through interview techniques. The study was conducted in real-world situations. Primary data, comprising mid-semester summative exam results from students sampled during the odd semester of the 2024/2025 academic year from three insitutions, was collected, along with additional data presented in the Figure 1.



	TTS XI 1	TTS XI 2	TTU XI 1	TTU XI 2	Belu X 1	Belu X 2
Standard Deviation	5,89	5,83	15,6	15	15,94	21,23
Average Grade	79,85	79,16	38,3	40	50,51	44,48
Minimal Grade	74	73	16,6	3,3	18	13,5
Maximal Grade	95	95	76,6	73,3	78,5	93
Number of Students	33	31	36	33	36	35

Figure 1. Mid-Semester Summative Value Analysis Results for Chemistry Material (Source: SMAN in TTS Regency, SMAN in TTU Regency, SMAN in Belu Regency, 2024. "Mid-Semester Odd Semester Summative Assessment Scores for the 2024/2025 Academic Year in Chemistry")

The preliminary data visualization in Figure 1 indicates significant differences in students' academic performance between schools and classes. Two classes from the TTS regency (XI-1 and XI-2) demonstrated consistently high academic performance, with mean scores of 79.85 and 79.16, respectively, as well as relatively high minimum scores (74 and 73), and low standard deviations (5.89 and 5.83). This indicates that the majority of students in both classes demonstrated an even and near-perfect mastery of the material, suggesting a strong homogeneity of initial ability.

In contrast, classes from TTU (XI-1 and XI-2) and Belu (X-1 and X-2) regencies show greater variation in mastery. In TTU, the average learner scores were well below the passing grade (75), at 38.3 and 40, with very low minimum scores (16.6 and 3.3) and high standard deviations (15.6 and 15.0). Similarly, classes X-1 and X-2 from Belu recorded average scores of 50.51 and 44.48, respectively, with high standard deviations

The difference in the distribution of these scores suggests that students' initial mastery of the material in the research area is not uniform, and this has a practical impact on the implementation strategy of the Chem-PjBL-L-NTT-W model. Therefore, further analysis in this study was conducted separately for each regency to consider the context of students' different initial abilities. In addition, teachers are encouraged to use this finding as a basis for forming academically homogeneous study groups, thereby supporting the effectiveness of Chem-PjBL-L-NTT-W, which is contextual, collaborative, and adaptive to students' conditions.

The construction of the Chem-PjBL-L-NTT-W instruments for each chemistry topic commences with the identification of the chemical material to be taught by the teachers, the recognition of the types and characteristics of local wisdom in NTT pertinent to each chemistry topic, and the formulation of the project theme.

The local wisdom of NTT and its relation to each chemical subject can be articulated. The primary subject of the periodic system and the electron arrangement of elements is associated with the concept of traditional dwellings in NTT. For instance, Uem Lopo and Ume Kbubu, traditional edifices of the Dawan tribe in TTS regency, exhibit a pyramidal form that narrows towards the apex, comprising three chambers across three tiers: the foundational level serves as a resting area, the intermediate level is designated for the storage of food and crops, and the uppermost level functions as a reserve supply area once the second level reaches capacity (Taneo & Neolaka, 2022). The three tiers, each serving a distinct purpose, embody specific philosophical principles that the present generation must uphold. Furthermore, Umametan Lawalu (Limahelu et al., 2019) and Uma Lulik, the traditional dwellings of the tribe in Belu Regency, feature four corners (*sikun hat*) that symbolize the belief in the four cardinal directions: the cooking stove (*lalian*), the house door (*oda matan*), the family gathering area (*leo laran*), and the place of worship (*foho*) (Tahu & Magalhaes, 2020). The notion of this classic house might be associated with the concept of electron configuration, which pertains to the arrangement of electrons according to the shells or orbitals of an atom. Bohr posits that electron filling commences at the lowest energy level (shell) (K shell/ first shell, n = 1). Upon complete occupation of the initial shell, the subsequent shell is filled in the following order: L shell (second shell, n = 2), M shell (third shell, n = 3), N shell (fourth shell, n = 4), and so forth. Assigning students to create a typical house model as a representation of the atomic structure of a specific element facilitates the integration of cultural values with the principles of chemistry, so enhancing their comprehension of both domains.

Secondly, the diverse natural elements employed as colors in the woven ikat fabric by the people in NTT can be associated with hydrocarbon substances. Nitti et al. (2022) found that the community in Amarasi Regency, Kupang Regency, NTT, uses young teak leaves (*Tectona grandis L.f.*) to produce a purple dye for thread fibers intended for weaving sarongs. Moreover, it is shown that the purple hue is derived from anthocyanin pigments, which are chemical substances belonging to the flavonoid family. By teaching students to recognize the presence of flavonoids in the pigments of plants from the NTT region, which have promise as natural dyes, it can cultivate scientific skills while consistently improving students' favorable attitudes towards chemistry, as it is intrinsically linked to local wisdom.

Thirdly, the primary content on the elements influencing chemical equilibrium can be attributed to the local wisdom of the NTT community, which includes traditional methods of salt production and palm sap fermentation for alcohol production. Salt is conventionally produced by dissolving coarse salt in well water, filtering the resulting solution through a rattan sieve, and subsequently boiling the filtered solution using a stove and firewood as heat sources. This procedure yields a salt akin to damp sand, which is subsequently dried and re-filtered through a lontar sieve (Sulastri et al., 2024). Students are instructed to conduct a project on the parameters that influence chemical equilibrium by manipulating temperature, surface area, and concentration in the conventional manufacturing of sodium chloride (NaCl). This enhances problem-solving abilities concerning the establishment of experimental objectives, formulation of problems and hypotheses, operational definition of variables, identification of tools, materials, and experimental procedures consistent with the local knowledge of NTT in salt production, documentation of observational data, analysis of data utilizing appropriate techniques, and derivation of conclusions from experimental results.

From this research, three project themes were identified, which form the basis for the development of the phases in Chem-PjBL-L-NTT-W, as detailed in Table 1.

Table 1. Integration of Chemistry Material with NTT Local Wisdom and Themes

No	Chemistry Material	Types of NTT Local Wisdom	Project Themes Used	Location
1	Hydrocarbon	Ikat Weaving (various regions in NTT)	Identification of the properties and reactions of hydrocarbon compounds in various local plants that can be used as alternative natural dyes for NTT woven fabrics	TTU
2	Electron configuration and the periodic table	Traditional houses from various regions in NTT	Traditional Houses of NTT Regencies as Atomic Models: Structure and Electron Arrangement in Important Elements	Belu
3	Factors affecting chemical equilibrium	Local wisdom of the NTT community in salt production	Identification of Factors Affecting Chemical Equilibrium in the Traditional Salt Production Process as NTT Local Wisdom	TTS

After acquiring the project subject presented in Table 1, the subsequent step is to delineate the learning phases and evaluative components for each phase. The learning process employs the phases of the project-based learning model, which include establishing learning objectives for students, ensuring comprehension of the necessary concepts, developing requisite skills, presenting the project theme, planning and designing the project, executing project activities in accordance with the design, and conveying the project through both oral and written communication (Jalinus et al, 2017).

The students' project steps are evaluated systematically through observation sheets for planning, designing, implementing, and reporting, with criteria and evaluation components for each phase consolidated into a total project score. Every phase of the study has demonstrated how students in groups are encouraged to employ CLS, including communication and collaboration, information integration, self-directed learning organization, and problem-solving strategy development. The CLS questionnaire tool was employed to assess students' assessments of these talents, with a response scale of strongly agree (5), agree (4), neutral (3), disagree (2), and strongly disagree (1) (Tian et al, 2023). The CLS instrument has undergone testing and has been deemed valid, exhibiting an item r-count value exceeding the table ($p < 0.01 = 0.449$ and $p < 0.05 = 0.325$), alongside a Cronbach's Alpha value of 0.818 for reliability.

The implementation of Chem-PjBL-L-NTT-W has facilitated the guidance of students in developing an appreciation for chemistry theory, proficiency in laboratory work, confidence in assessments, and a propensity for studying chemistry. Cheung (2011) utilized these indicators to formulate the ATCL Questionnaire, which is employed in this study with the following scale: strongly disagree (1), somewhat disagree (2), slightly disagree (3), unsure (4), slightly agree (5), somewhat agree (6), and strongly agree. (7). The ATCL instrument has been evaluated and deemed valid, exhibiting estimated r-values for each item exceeding the table r-values ($p<0.01= 0.449$ and $p<0.05= 0.325$), alongside a Cronbach's Alpha of 0.800 for reliability.

Qualitative data regarding the challenges encountered by educators in implementing Chem-PjBL-L-NTT-W were collected through semi-structured interviews. Simultaneously, students' evaluations of the execution of this learning were assessed through interviews using questions modified from Tian et al. (2023). Additional interview questions were prepared based on significant insights from the quantitative data analysis. The procedure for developing and implementing Chem-PjBL-L-NTT-W can be outlined in Figure 2.

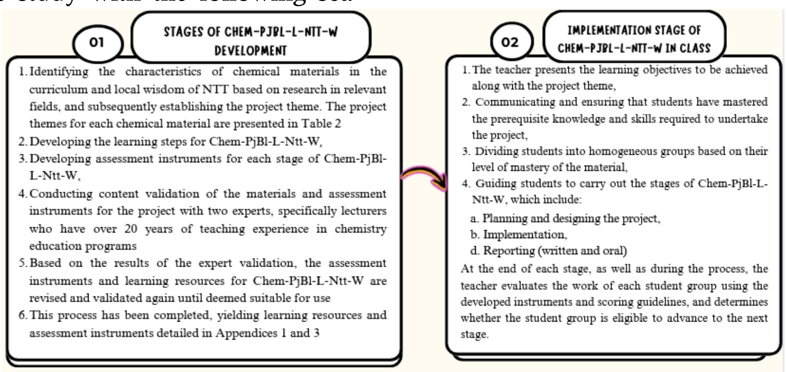


Figure 2. The Procedure for Development and Implementation of Chem-PjBL-L-NTT-W

Based on Figure 2, it can be stated that the development of Chem-PjBL-L-NTT-W begins with identifying the characteristics of chemistry materials and the local wisdom of NTT to produce learning devices and assessment instruments, as shown in Appendices 1 and 3 (https://drive.google.com/file/d/1Y9DnTGjl-QsN9xR4N4-kd_QSlUHWVtkb/view?usp=drive_link). Furthermore, teachers utilize these learning devices and assessment instruments to implement effective teaching and learning activities.

The flow and research procedures for implementing Chem-PjBL-L-NTT-W to assess CLS and ATCL are shown in Figure 3.

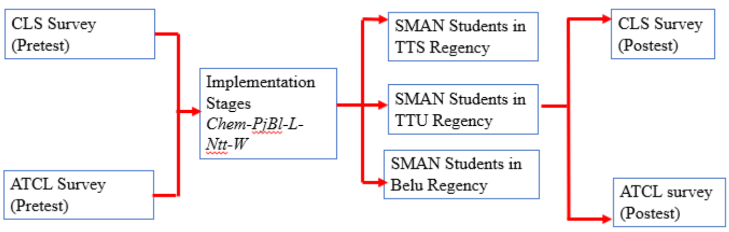


Figure 3. Flow and Research Procedures in the Implementation of Chem-PjBL-L-NTT-W

Based on Figure 3, it can be revealed that the implementation of Chem-PjBL-L-NTT-W to assess CLS and ATCL begins with conducting an initial survey (pre-test) using the CLS and ATCL questionnaire. Then each teacher implemented the Chem-PjBL-L-NTT-W stage and ended with a final survey (post-test). These stages were conducted separately in each school located in each regency.

The flow and research procedures for implementing Chem-PjBL-L-NTT-W to assess students' concept comprehension are shown in Figure 4.

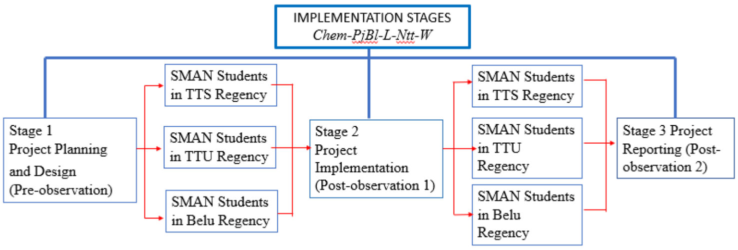


Figure 4. The Implementation of Chem-PjBL-L-NTT-W to Assess Students' Conceptual Comprehension

Based on Figure 4, it can be stated that there are three stages to assess students' concept comprehension in the implementation of Chem-PjBL-L-NTT-W. Sequentially, stages 1, 2, and 3 involve planning and designing, implementation, and project reporting. During the implementation of each stage of Chem-PjBL-L-NTT-W, the teacher assesses student performance using the developed instruments (Appendices 1 and 3 in https://drive.google.com/file/d/1Y9DnTGjl-QsN9xR4N4-kd_QSlUHWVtkb/view?usp=drive_link) to obtain pre-observation, post-observation 1, and post-observation 2 scores.

The analysis of CLS, ATCL, and concept comprehension data commences with a normality assessment utilizing the Kolmogorov-Smirnov test. Subsequently, regularly distributed data are quantitatively examined using a paired t-test, while non-normally distributed data are assessed with the Wilcoxon signed-rank test in SPSS version 23.0. The data also underwent analysis to examine effect sizes and confidence intervals (CIs). Descriptive analysis is employed to compare CLS, ATCL, and students' conceptual knowledge among three groups of students across three schools. The qualitative analysis of teacher and student interview transcripts is employed to provide corroborative descriptions for the quantitative analysis findings.

RESULTS AND DISCUSSION

The data pertinent to the aims examined in this research comprises information from students who were completely engaged from the inception to the conclusion of the investigation. In TTS regencies, 64 students from SMAN participated, while in TTU, 65 out of 69 students were involved, and in Belu, 41 out of 71 students participated. Analysis of pre-test and post-test data indicates that a significance value of <0.05 denotes non-normally distributed data, whereas a value of >0.05 signifies normally distributed data. This outcome can be presented in Table 2.

Table 2. Kolmogorov-Smirnov Test for Normality of Crucial Learning Skills

Students' Regency	Dependent Variable	Kolmogorov-Smirnov[a]					
		Statistic	df	Sig.	Statistic	Df	Sig.
		Pre-test			Post-test		
TTS	CLS	,198	64	,000	,145	64	,002
TTU	CLS	,085	65	,200*	,061	65	,200*
Belu	CLS	,152	41	,018	,144	41	,032

*. This is a lower bound of the true significance.
[a]. Lilliefors Significance Correction

Non-normally distributed data was examined using the Wilcoxon Signed Ranks Test, whereas regularly distributed data was studied using the T-Paired test. The data analysis results indicate that students at SMAN in the TTS regency showed an increase in CLS scores, as evidenced by 64 positive rankings. The Z value is -6.960, and the Asymptotic Significance (2-tailed) is 0.000, which is less than 0.05, indicating a significant difference between the pre-test and post-test scores. The effect size value r = 0.870, and 95% confidence intervals CI: [0.79, 0.92] indicates that Chem-PjBL-L-NTT-W has a substantial and consistent effect on improving students' CLS. The entire range of intervals showed significant effects, indicating these results are stable and practically significant.

The CLS data analysis results for children in the Belu regency suggest that 12 students exhibited a decline in CLS scores, while 26 students showed an improvement, as reflected by the respective negative and positive ranks. The Z value is -2.163, and the Asymptotic Significance (2-tailed) is 0.031, which is less than 0.05, indicating a significant difference between the pre-test and post-test scores. Value (r): 0.338, 95% CI: [0.03, 0.58] indicates that Chem-PjBL-L-NTT-W has a moderate effect on improving students' CLS. Although the lower limit approximates a small effect, the upper limit suggests a potentially large effect; therefore, this effect is generally considered practically meaningful. The results are presented in Table 3.

Table 3. Wilcoxon Signed Ranks Test for Students' Crucial Learning Skills in Timur Tengah Selatan and Belu

Post-test - Pre-test for CLS in Each Regency	Ranks				Test Statistics[a]	
		N	Mean Rank	Sum of Ranks	Z	Asymp. Sig. (2-tailed)
TTS	Negative Ranks	0[a]	,00	,00	-6,960[b]	,000
	Positive Ranks	64[b]	32,50	2080,00		
	Ties	0[c]				
	Total	64				
Belu	Negative Ranks	12[a]	18,46	221,50	-2,163[b]	,031
	Positive Ranks	26[b]	19,98	519,50		
	Ties	3[c]				
	Total	41				
	a. Post-test < Pre-test				a. Wilcoxon Signed Ranks Test	
	b. Post-test > Pre-test				b. Based on negative ranks.	
	c. Post-test = Pre-test					

The CLS analysis of high school students in the TTU area revealed a pre-test mean score of 60.74 and a post-test mean score of 70.72, signifying an improvement in the average CLS score. The mean difference is -9.985, t = -8.969, the significance (2-tailed) is 0.000 < 0.05, and 95% CI: [-12.208, -7.761], indicating a significant difference between the pre-test and post-test CLS. However, the value of Cohen's d = 0.19 indicates that the treatment effect is very small. The results are presented in Table 4.

Table 4. Paired T-Test for Students' Crucial Learning Skills in Timur Tengah Utara

	Paired Samples Statistics				Paired Samples Correlations		
	Mean	N	Std. Deviation	Std. Error Mean	N	Correlation	Sig.
Pre-test (CLS)	60,74	6	7,098	,880	65	,231	,064
Post-test (CLS)	70,72	65	7,371	,914			

Paired Samples Test								
	Paired Differences					t	Df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pre-test (CLS) - Post-test (CLS)	-9,985	8,975	1,113	-12,208	-7,761	-8,969	64	,000

Tables 3 and 4 indicate that the adoption of Chem-PjBL-L-NTT-W has substantially enhanced the CLS of high school students across the three regencies, with region-specific variations in impact.

The CLS questionnaire is divided into four categories (Tian et al, 2023). Initially, communication and collaboration encompass the statement in item four. (I3) I influence others when I hold differing opinions, (I4) I articulate my thoughts systematically when representing the group, (I7) I enjoy exchanging ideas with others, and (I9) I collaborate with group members to accomplish goals. Secondly, Information integration comprises statements. (I1) I believe that chemistry-related information is prevalent in our daily lives, (I8) I am proficient in locating websites and resources about chemistry, (I11) I seek assistance from people on challenging subjects, (I14) I am aware of multiple methods to acquire chemistry-related information. Third, Independent Learning encompasses declarations. (I6)

I can fulfill duties provided by the teacher prior to learning, (I10) I efficiently manage my study time outside of class, (I12) I occasionally engage in activities I have not undertaken before, (I15) I delineate areas for improvement in my learning. Fourth, problem-solving encompasses (I2) my enjoyment of collaborating with others to address issues, (I5) my ability to apply my chemical knowledge to resolve difficulties, (I13) my capacity for clear thinking during problem-solving, and (I16) my tendency to identify more solutions to a problem than others.

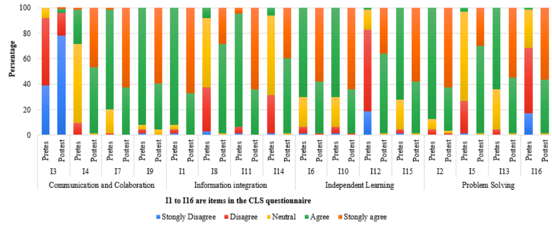


Figure 5. Students' Responses to the Questionnaire of Crucial Learning Skills in Timur Tengah Selatan

The Y-axis in Figure 5 represents the percentage of students/respondents who strongly disagree (blue bar graph slices), disagree (red), are neutral (yellow), agree (green), or strongly agree (orange). On the X-axis, the symbols I3, I4, I7, and so on represent the CLS questionnaire statements numbered 3, 4, 7, and so on in both the test and post-test. The explanation in Figure 5 defines the other graphs in this discussion with adjustments.

The responses of SMAN students in the TTS regency towards CLS, as depicted in Figure 5, can be elucidated. Students seem to possess a remarkable understanding of their CLS. This analysis is derived from student responses prior to the adoption of Chem-PjBL-L-NTT-W, indicating that the replies to the four dimensions of CLS predominantly aligned with the "agree" criteria, with the exceptions of I4, I8, I14, and I15, each corresponding to the four dimensions of CLS and categorized as "neutral." I3, I12, and I16 are classified among the "disagree" and "strongly disagree" categories. Following the implementation of Chem-PjBL-L-NTT-W, the predominant replies transitioned to "agree" and "strongly agree." This demonstrates that the phases in the learning process utilizing the Chem-PjBL-L-NTT-W gadget effectively enhanced students' views of CLS. It is worth noting that I3 experienced a significant increase in responses from "disagree" to "strongly disagree." Students appear to disagree with the term "persuade" in I3. Students assert, based on interview findings, that their viewpoints must be supported by credible, logical evidence to persuade peers with differing perspectives.

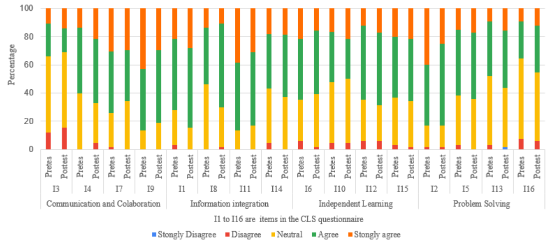


Figure 6. Students' Responses to the Questionnaire of Crucial Learning Skills in Timur Tengah Utara

Based on Figures 6 and 7, the comments of high school students in TTU and Belu regencies on CLS may be articulated. The graph patterns of these two student groups appear to be analogous. A marginal rise was observed in the "disagree" and "strongly agree" categories for I3, I4, I8, I14, and I5 among high school students in the TTU regency, as well as for I3, I4, I8, I14, and I5 among students in SMAN in Belu regency. In all statements preceding and following the adoption of Chem-PjBL-L-NTT-W, the majority remained predominant, with a marginal increase in the "neutral", "agree," and "strongly agree" categories. The majority of students exhibited a favorable view of CLS prior to the treatment and demonstrated enhancement post-treatment.

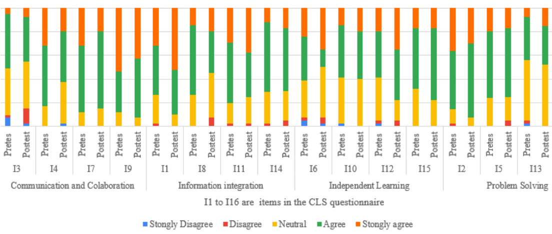


Figure 7. Students' Responses to the Questionnaire of Crucial Learning Skills in Belu

The analysis of CLS data from three high schools in each regency suggests that the implementation of Chem-PjBL-L-NTT-W greatly enhances CLS perception among high school students in the TTS regency, whereas the rise is less pronounced for students in the TTU and Belu regency.

The analysis of pre-test and post-test data for ATCL students from public senior high schools in TTS, TTU, and Belu regency reveals that a significance value of <0.05 suggests a non-normal distribution, while a value of >0.05 indicates a normal distribution. The results can be presented in Table 5.

Table 5. Kolmogorov-Smirnov Test for Normality of Attitudes Toward Chemistry Learning

Students' Regency	Dependent Variable	Kolmogorov-Smirnov[a]					
		Statistic	df	Sig.	Statistic	df	Sig.
		Pre-test			Post-test		
TTS	ATCL	,091	64	,200*	,097	64	,200*
TTU	ATCL	,101	65	,168	,090	65	,200*
Belu	ATCL	,121	41	,140	,170	41	,005

*. This is a lower bound of the true significance.
[a]. Lilliefors Significance Correction

Data that is not normally distributed is examined using the Wilcoxon Signed Ranks Test, whereas normally distributed data is assessed using the T-Paired test. The data analysis results reveal that students at public senior high schools in TTS regency exhibited a significant increase in the average ATCL score, rising from a pre-test mean of 36.41 to a post-test mean of 78.36, a 41.953-point increase. The t-value is -35.679, the two-tailed significance value is 0.000, which is less than 0.05, and value 95% CI value:[-44,303, -39,603], suggesting a significant difference between the pre-test and post-test ATCL. The value of Cohen's d = 0.95 indicates that the observed differences are not merely coincidental, but also have a very strong practical impact. The applied treatment is highly effective in improving ATCL scores. The examination of ATCL data for SMAN students in TTU area reveals an average score enhancement of 3.800, with a pre-test mean of 68.95 and a post-test mean of 72.75. The t-value is -3.756, and the two-tailed significance value is 0.000, which is less than 0.05, 95% CI:[-5,821, -1,779] signifying a significant difference between the pre-test and post-test ATCL. However, Cohen's D= 0.09 indicates a very small effect size. This means that although the improvement in ATCL scores after treatment was evident and not due to chance (statistically significant), the magnitude of the improvement was practically minimal or insubstantial. The results are presented in Table 6.

Table 6. Paired T-Test for Students' Attitudes Toward Chemistry Learning in Timur Tengah Utara and Timur Tengah Selatan

	Paired Samples Statistics				Paired Samples Correlations		
	Mean	N	Std. Deviation	Std. Error Mean	N	Correlation	Sig.
Pre-test (ATCL)/TTS	36,41	64	8,963	1,120	64	,003	,982
Post-test (ATCL)/TTS	78,36	64	2,881	,360			
Pre-test (ATCL)/TTU	68,95	65	6,723	,834	65	,192	,125
Post-test (ATCL)/TTU	72,75	65	6,091	,755			

Paired Samples Test

	Paired Differences					t	Df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pre-test (ATCL) and Post-test (ATCL)/TTS	-41,95	9,407	1,176	-44,303	-39,603	-35,679	63	,000
Pre-test (ATCL) and Post-test (ATCL)/ TTU	-3,800	8,157	1,012	-5,821	-1,779	-3,756	64	,000

The ATCL data analysis results for SMAN students in Belu regency indicate that 21 students exhibited a decline in ATCL scores (Negative Ranks), whereas 18 students demonstrated an increase (favorable rankings). The Z value of -0.189 and an Asymptotic Significance (2-tailed) value of 0.850, which exceeds 0.05, suggest the absence of a significant difference between the pre-test and post-test ATCL. Value (r): 0.030, and 95% CI: [-0.28, 0.33] indicating that the impact of the change in ATCL scores from pre-test to post-test was very small, almost non-existent and that the confidence interval included zero and had a wide range, further reinforcing that there is no strong evidence of a consistent or substantial effect in practice on students in Belu. The results of this investigation can be presented in Table 7.

Table 7. Wilcoxon Signed Ranks Test for Students' Attitudes Toward Chemistry Learning in Belu

		Ranks			Test Statistics[a]	
		N	Mean Rank	Sum of Ranks	Z	Asymp. Sig. (2-tailed)
Post-test - Pre-test (ATCL)	Negative Ranks	21[a]	19,21	403,50	-,189[b]	,850
	Positive Ranks	18[b]	20,92	376,50		
	Ties	2[c]				
	Total	41				
		a. Post-test < Pre-test			a. Wilcoxon Signed Ranks Test	
		b. Post-test > Pre-test			b. Based on negative ranks.	
		c. Post-test = Pre-test				

Based on the data analysis results in Tables 5, 6, and 7, it can be stated that the implementation of Chem-PjBL-L-NTT-W has a significant impact on the improvement of ATCL among high school students in TTS and TTU regencies; however, it does not have a significant effect on high school students in Belu regency. This may be due to other factors that need to be further examined.

In the ATCL questionnaire developed by Cheung (2011), 12 statement items are categorized into four aspects. First, it includes (Q1) I like chemistry more than any other school subject, (Q5) learning chemistry is interesting, and (Q9) Chemistry is one of my favorite subjects. Second, my liking for chemistry laboratory work consists of (Q2) I enjoy doing chemistry experiments, (Q6) When I am working in the chemistry lab, I feel I am accomplishing something important, and (Q10) I find chemistry experiments enjoyable in school. Third, evaluative beliefs about school chemistry, including (Q3) Chemistry is useful for solving everyday problems, (Q7) People must understand chemistry because it affects their lives, (Q11) Chemistry is one of the most important subjects for people to study. Fourth, Behavioral tendencies to learn chemistry, consist of (Q4) I am willing to spend more time reading chemistry books, (Q8) I like trying to solve new problems in chemistry, (Q12) If I had a chance, I would do a project in chemistry.

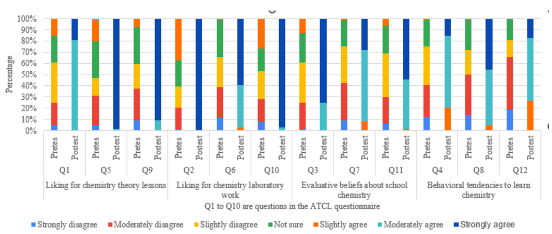


Figure 8. Students' Responses to the Questionnaire of Attitudes Toward Chemistry Learning in Timur Tengah Selatan

Upon close observation of Figure 8, it is evident that the responses of high school students in the TTS regency to the ATCL questionnaire yielded fascinating results. Before the implementation of Chem-PjBL-L-NTT-W, students' responses varied in the dominant categories of "not sure," "slightly disagree," and "moderately disagree," followed by "slightly agree" and "strongly disagree." This indicates that students' ATCL was still relatively low. After the treatment, the majority of students' responses drastically shifted to the categories of "strongly agree" and "moderately agree." Therefore, the implementation of Chem-PjBL-L-NTT-W was highly effective, as it resulted in a significant increase in all four aspects of ATCL.

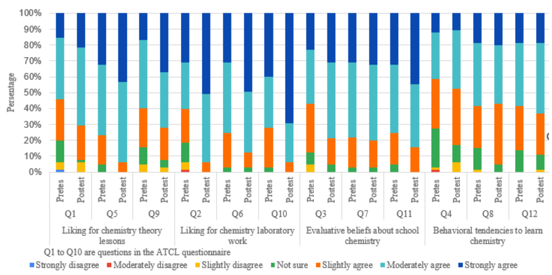


Figure 9. Students' Responses to the Questionnaire of Attitudes Toward Chemistry Learning in Timur Tengah Utara

Based on Figures 9 and 10, it can be observed that the trend of increasing ATCL responses from high school students in TTU and Belu Regency exhibits a similar pattern. Prior to the implementation of Chem-PjBL-L-NTT-W, the majority of students already had a good ATCL. This is indicated by the majority of student responses in the various categories, predominantly in the categories of "Moderately agree," "Slightly agree," and "Strongly agree." After the implementation of Chem-PjBL-L-NTT-W, there was also a varied increase in these categories. Thus, the implementation of Chem-PjBL-L-NTT-W is effective in improving the ATCL of high school students in these two regencies, although the improvement is not significant.

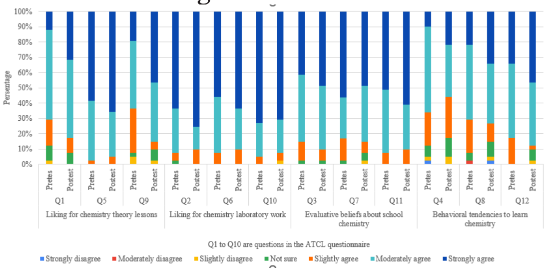


Figure 10. Students' Responses to the Questionnaire of Attitudes Toward Chemistry Learning in Belu

Based on Figures 8, 9, and 10, it is evident that the implementation of Chem-PjBL-L-NTT-W, encompassing the stages of planning and design, execution, and reporting, has successfully improved the students' ATCL. Significant improvement was experienced by high school students in TTS regency, and a lower improvement was observed among high school students in TTU and Belu regency.

The data on the concept comprehension scores of high school students in three regencies, covering the planning and design stage, implementation, and project report during the implementation of Chem-PjBL-L-NTT-W, were tested for normality. All data were declared not normally distributed (Kolmogorov-Smirnov Sig. value for all data 0.000 < 0.05). The results of this analysis are displayed in Table 8.

Table 8. Kolmogorov-Smirnov Test for Normality of Concept Comprehension

Students' Regency	Dependent Variable	Kolmogorov-Smirnov[a]								
		Statistic	df	Sig.	Statistic	Df	Sig.	Statistic	df	Sig
		Pre-observation			Post-observation 1			Post-observation 2		
TTS	Concept Comprehension	,213	64	,000	,192	64	,000	,205	64	,000
TTU		,202	65	,000	,118	65	,025	,170	65	,000
Belu		,379	41	,000	,348	41	,000	,272	41	,000

*. This is a lower bound of the true significance.
[a]. Lilliefors Significance Correction

Referring to the test results indicating that the data on students' concept comprehension are not normally distributed, the next test used is the Wilcoxon Signed-Rank test. Based on the analysis of the concept comprehension data from high school students in three regencies, the results show a decrease in scores from post-observation 2 to post-observation 1 (for TTS and TTU regencies). Meanwhile, for the Belu regency, there is still an increase in value. For all regencies and all types of tests, the Asymp. Sig. (2-tailed) value of 0.000 < 0.05 indicates a significant difference in students' conceptual understanding after the treatment at each stage of Chem-PjBL-L-NTT-W. Supported by all (r) values >0.50 and their respective 95% CI values indicate that the effect of Chem-PjBL-L-NTT-W at each stage is practically strong, and has a real impact. The results of this analysis are presented in Table 9.

Table 9. Wilcoxon Signed Ranks Test for Concept Comprehension

Students' Location			Ranks			Test Statistics[a]		
			N	Mean Rank	Sum of Ranks	Z	Asymp. Sig. (2-tailed)	Effect size (r) and CI
TTS	Post Observation 1- Pre Observation	Negative Ranks	6[a]	3,50	21,00	-6,820[b]	,000	(r): 0.853 95% CI: [0.77, 0.91]
		Positive Ranks	58[b]	35,50	2059,00			
		Ties	0[c]					
		Total	64					
	Post Observation 2- Post Observation 1	Negative Ranks	60[a]	33,48	2009,00	-6,858[b]	,000	(r): 0.857 95% CI: [0.77, 0.91]
		Positive Ranks	3[b]	2,33	7,00			
		Ties	1[c]					
		Total	64					

TTU	Post Observation 1- Pre Observation	Negative Ranks	6[a]	18,50	111,00	-6,300[b]	,000	(r): 0.781 95% CI: [0.66, 0.86]
		Positive Ranks	59[b]	34,47	2034,00			
		Ties	0[c]					
		Total	65					
	Post Observation 2- Post Observation 1	Negative Ranks	65[a]	33,00	2145,00	-7,076[b]	,000	(r): 0.878 95% CI: [0.81, 0.92]
		Positive Ranks	0[b]	,00	,00			
		Ties	0[c]					
		Total	65					
Belu	Post Observation 1- Pre Observation	Negative Ranks	0[a]	,00	,00	-5,929[b]	,000	(r): 0.926 95% CI: [0.86, 0.96]
		Positive Ranks	41[b]	21,00	861,00			
		Ties	0[c]					
		Total	41					
	Post Observation 2- Post Observation 1	Negative Ranks	0[a]	,00	,00	-5,203[b]	,000	(r): 0.813 95% CI: [0.67, 0.90]
		Positive Ranks	35[b]	18,00	630,00			
		Ties	6[c]					
		Total	41					
	Post Observation 1- Pre Observation	Post Observation 1 < Pre Observation						
		Post Observation 1 > Pre Observation						
		Post Observation 1 = Pre Observation						
	Post Observation 2- Post Observation 1	a. Post Observation 2 < Post Observation 1				a. Wilcoxon Signed Ranks Test		
		b. Post Observation 2 > Post Observation 1				b. Based on negative ranks.		
		c. Post Observation 2 = Post Observation 1						

Based on Figure 11, it can be concluded that high school students in TTS regency show an increase in conceptual understanding at the implementation stage, but a decrease at the reporting stage. Somewhat different from the students in TTU regency, who experienced a steady increase from the planning and implementation stages to the implementation and reporting stages. However, there was a slight decrease in the reporting stage. As for high school students in Belu Regency, they showed the highest improvement in the reporting stage but only experienced a slight increase in implementation. They started the planning and design stages with lower average scores than in the subsequent stages. The tendency for the average score to decline at the reporting stage in TTS and TTU regency may be due to the project report being required to be completed individually unlike the previous stage, which involved collaboration among students in groups and teacher guidance during the planning, design, and implementation phases of the project, this stage involved collaboration among students in groups and teacher guidance during the planning, design, and implementation phases of the project.

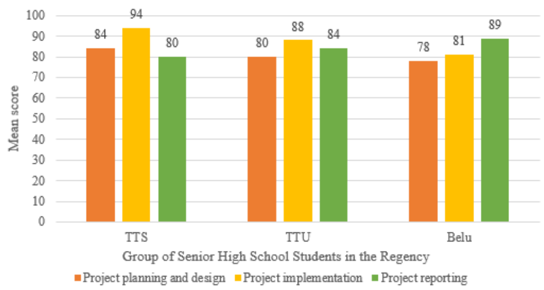


Figure 11. Students' Average Scores at Each Stage of Chem-PjBL-L-NTT-W

Based on Figure 11, it can be concluded that high school students in TTS regency show an increase in conceptual understanding at the implementation stage, but a decrease at the reporting stage. Somewhat different from the students in TTU regency, who experienced a steady increase from the planning and implementation stages to the implementation and reporting stages. However, there was a slight decrease in the reporting stage. As for high school students in Belu Regency, they showed the highest improvement in the reporting stage but only experienced a slight increase in implementation. They started

the planning and design stages with lower average scores than in the subsequent stages. The tendency for the average score to decline at the reporting stage in TTS and TTU regency may be due to the project report being required to be completed individually unlike the previous stage, which involved collaboration among students in groups and teacher guidance during the planning, design, and implementation phases of the project, this stage involved collaboration among students in groups and teacher guidance during the planning, design, and implementation phases of the project.

Teachers Interviews

To strengthen the research findings on the constraints faced, interviews were conducted with the three teachers who implemented Chem-PjBL-L-NTT-W.

What are the obstacles faced in the implementation of Chem-PjBL-L-NTT-W?

From Belu

"I regret to inform you that the implementation of Chem-PjBL-L-NTT-W has encountered various difficulties. As a teacher, I find it challenging to arrange time for supervising student projects. I must engage in multiple educational activities, including driving instruction, chemistry tutoring for various student groups, participation in professional teacher education initiatives, and preparation for the government employee selection process under a work agreement. The students expressed dissatisfaction over the volume of homework from other topics, which resulted in a time deficit. As a teacher, I persist in accommodating this, guiding them incrementally and directing them to ensure the completion of their learning. This understanding is essential for helping students grasp the concept of chemistry. Furthermore, the scaled-down typical NTT house model can be stored in the classroom and then utilized to elucidate the concept of electron configuration for various elements."

From Timur Tengah Utara

"Project-based learning, integrating local wisdom, is new to me. Consequently, I require further guidance and clarification concerning these stages during the implementation process. The tiered implementation necessitates additional time from students beyond normal lectures. Nonetheless, numerous extracurricular activities within the school calendar impede this learning endeavor, including Independence Day festivities, Youth Pledge events, Language and Culture Month, school monitoring initiatives, and IHT activities for digitization. These exercises engage both students and teachers. This consumes a significant portion of our learning time. Occasionally, the chemistry curriculum, as delivered through traditional pedagogical approaches, is not comprehensively addressed. Nonetheless, I believe that the core of the Chem-PjBL-L-NTT-W learning practice imparts more significant knowledge to my students; so, I persist in engaging with them in class, inquiring about their leisure activities, and finalizing this project."

From Timur Tengah Selatan

"The completion of this lesson may be somewhat postponed. I am presently engaged in PPG and the teacher competency examination. I request authorization to utilize the Chem-PjBL-L-NTT-W learning process in the PPG activities in which I am presently engaged. I find this matter intriguing. The majority of my students possess inadequate proficiency in the Indonesian language due to their predominant use of regional languages. Nonetheless, the project, which emphasizes chemistry education linked to local wisdom, enhances their motivation to learn, and they also receive parental support to utilize their time outside of school effectively. The principal expressed enthusiasm for the learning activity, having actually watched it, and deemed it highly creative for employing an environment-based teaching strategy. Consequently, despite the absence of a laboratory in our school, environmentally focused projects and indigenous knowledge can impart an understanding of chemistry to our students."

Interview with Students

Question 1. Is this Chem-PjBL-L-NTT-W learning new to you? Which one do you prefer, this learning method or the one your teacher has been using all this time?

From Timur Tengah Utara (1)

"Yes, this is new to me, especially the research method or learning approach conducted through the experimental process. I prefer the Chem-PjBL-L-NTT-W learning process over the learning processes I have followed frequently before."

From Timur Tengah Utara (2)

"Yes, for me. I like both. However, I prefer the learning methods that our teacher usually uses."

From Belu (1)

"Yes, this is very new to me. Moreover, I prefer learning like this because it is interesting, makes me understand quickly, and is not boring or monotonous compared to studying using textbooks."

From Belu (2)

"Indeed, this is new for me. Interesting and enjoyable. I prefer this compared to previous learning. The reason is that this material makes the concept of chemistry feel more tangible; the traditional house is a very suitable representation for the atomic model material, making it easier for students to visualize how atomic concepts work."

Question 2. Does this Chem-PjBL-L-NTT-W help you? If yes, or if no, why?

From Timur Tengah Utara (1)

"Chem-PjBL-L-NTT-W is very helpful because it includes experimental methods, which are an effective learning process, and it greatly aids me in understanding chemistry materials."

From Timur Tengah Utara (2)

"Yes, it helps me because it provides new insights about natural dyes used in ikat weaving by the people of NTT."

From Belu (1)

"Yes, it is invaluable because using the local wisdom of traditional houses makes me understand better, as it gives a real and closer picture of everyday life. I appreciate the local culture more, and I am increasingly interested in studying chemistry. In addition, I find it easier to understand the concept of electron configuration compared to other learning methods."

From Belu (2)

"Very helpful. Usually, chemistry concepts like the atomic model are difficult to understand because they are only seen through pictures or models in books. However, when the concept of the atomic model was explained using the analogy of a traditional house, I became more understanding of how the parts of the atom, such as protons, electrons, and neutrons, function. I became interested in learning because it felt like discovering something new. Moreover, what I like most about this learning is that it makes students imagine the atomic model, so the material or desired goals are straightforward for students to achieve."

Question 3. Does Chem-PjBL-L-NTT-W add extra burden to your studies? Why?

From Timur Tengah Utara (1)

"Every learning method has its own burden, and for learning with Chem-PjBL-L-NTT-W, it does not impose any extra burden on me. Although there were some obstacles, I overcame them with a sense of curiosity and enthusiasm."

From Timur Tengah Utara (2)

"Yes, it adds to the workload, but only a little. The reason is that the Chem-PjBL-L-NTT-W course requires practical work, which takes up a small amount of my time."

From Belu (1)

"It does not add extra burden for me; I actually find chemistry enjoyable. I can better manage my time to meet this demand amidst my busy study schedule."

From Belu (2)

"The burden is only when making a replica of the traditional house. On the other hand, it requires a little extra effort, but it actually provides me with new experiences and insights, making the burden feel worthwhile. I enjoy this learning process and the many benefits I gain from it."

Question 4. What is your suggestion for the future implementation of Chem-PjBL-L-NTT-W?

From Timur Tengah Utara (1)

"This type of learning needs to be maintained and should be conducted every semester so that it can help in understanding chemistry material and the connection between chemistry and the local culture and wisdom in NTT."

From Timur Tengah Utara (2)

"There is a small part of the experiment in our group's design that we did not have time to conduct. The suggestion is that the experimental procedure needs to be carried out to completion. However, I find this learning experience very enjoyable."

From Belu (1)

"So that teachers can better integrate local wisdom from various regions in NTT into any learning, making it easier to understand and more interesting, and thereby increasing my interest in learning and making it less boring."

From Belu (2)

"This learning is very innovative. The idea of using traditional houses as atomic models is a creative and innovative approach, distinct from previous methods. Additionally, it helps us to engage in the learning process actively; for example, we are more enthusiastic in discussing how to explain the concept of electron configuration using the concept of traditional houses. This method provides a fun and non-monotonous learning experience. I hope that this kind of learning can be applied in future learning, and for other materials, I would like to see connections with other local wisdoms from NTT."

Question 5. How was the collaboration and communication (cooperation among friends in the group) during the local wisdom-based chemistry learning? Are there any obstacles you faced? If there are any, what are the challenges that arise?

From Timur Tengah Utara (1)

"We find it difficult to collaborate because our time to meet is very limited. Even during group work, we do not have time to discuss directly at school except during chemistry class. This is because chemistry is an elective subject, so my group members and I are not in the same fixed class. We can only meet twice a week. In terms of communication, we also face difficulties. Face-to-face meetings cannot be conducted intensively for the same reason; therefore, we use social media, specifically WhatsApp, for this purpose. However, some friends are hindered by not having an internet package, which makes them less active in communicating and sharing ideas or suggestions. The solution I implemented was to share project planning ideas for feedback from friends in the group."

From Timur Tengah Utara (2)

"The cooperation among friends is quite good, because my friends and I express ideas to each other, discuss them, and decide what we need to do in planning and designing."

From Belu (1)

"Collaboration and communication are going very well. We discuss and share ideas, and we help each other understand the material through the provided examples. The challenges included the presence of group members who were less actively involved in the project, which burdened the other group members; differences in opinions; and differences in available time, as we had other tasks to complete. However, despite those challenges, our project was completed successfully."

Question 6. How do you convince your group members that your idea/opinion during chemistry learning related to local wisdom should be accepted?

From Timur Tengah Utara (1)

"I provide valid evidence or explain the research results I have found from articles and so on, first understanding and explaining them in my own way so that my friends can understand my ideas and opinions."

From Timur Tengah Utara (2)

"I provide a general understanding and give examples or evidence and facts that have already occurred so that they believe and are convinced that it is true and it can be done."

From Belu (1)

"When I have an idea and opinion, I will try to explain it simply and clearly so that my friends can understand my point. I also provide definite and logical reasons. I am also open to listening to my friends' opinions. We then discuss together to find common ground, so that our opinions can be united without disregarding the ideas or opinions of other friends. There is no pressure to follow only one member's idea, but we always present our individual arguments and then discuss to provide the best for our group."

The strategies employed to provide students with CLS and ATCL are apparent in the Chem-PjBL-L-NTT-W steps that have been formulated and implemented for chemistry learning. The Chem-PjBL-L-NTT-W toolkit used has defined the project concept, formulated appropriate learning stages, and provided evaluation tools for each stage. This process has thus immersed students in complex real-world projects that require them to identify, analyze, and solve problems. At the same time, it encourages critical thinking, strategic planning, and systematic organization of ideas, pushing students beyond rote to deeper cognitive engagement (Zhang & Ma, 2023; Husin et al., 2025). Students are encouraged to synthesize information from diverse sources, collaborate, and reflect on their approach, which strengthens their analytical and evaluative skills (Zhang et al., 2024)

All questioned students and teachers characterized project-based learning that incorporates local wisdom from NTT as a novel approach. Consequently, the teachers solicit counsel from the researchers regarding its execution. Seventy-five percent of the students interviewed favored learning using Chem-PjBL-L-NTT-W over their prior chemistry sessions. The reasons include practical activities, the application of scientific methodologies in basic research, engagement, facilitating rapid comprehension, enhancing imagination about abstract chemical concepts such as electron configurations, and avoiding monotony. All questioned students indicated that Chem-PjBL-L-NTT-W was significantly beneficial in offering new perspectives on the local knowledge of NTT, which could be incorporated into chemistry education, enhancing students' appreciation for local culture and fostering their enthusiasm for learning.

Furthermore, all the students indicated that Chem-PjBL-L-NTT-W was not excessively demanding for them. The examination of the interview transcripts about this issue revealed diverse student experiences. Four salient points emerged from the interviews with the four students: first, students acknowledge that each learning method, along with its associated challenges, is a natural occurrence; second, practical activities occupy a minimal portion of the students' time; third, students assert that they successfully organized their time despite their busy schedules and met all the demands of their learning; fourth, students necessitate additional effort to acquire new experiences and insights in this educational process. Concerning students' recommendations for Chem-PjBL-L-NTT-W in the future, it should be sustained and conducted each semester, executed comprehensively, necessitate the exploration of further local wisdoms of NTT in chemistry education, and be applied to other chemical subjects.

The findings of this study align with the assertions of Zidny et al. (2021), indicating that students received favorable feedback on chemistry education that incorporated local chemical elements alongside other relevant characteristics, deeming it engaging and pertinent.

During the planning and design phase, students in uniform groups are instructed to engage in discussions to establish the objectives of a straightforward project or research pertinent to the project subject. Subsequently, they conduct a literature review relevant to their project's investigation concepts, articulate the research problem, develop the hypothesis, identify variables, operationally define these variables, establish experimental protocols, design procedural methodologies, and determine the necessary tools and materials for the experiment, along with selecting suitable data analysis techniques. At this juncture, it is apparent that students must engage in collaboration and communication within groups, incorporate chemical concepts in formulating the investigation project, and delineate steps for problem-solving (Matilainen et al, 2021; Ananda et al, 2023; Pratiwi & Ikhsan, 2024; Handayani & Nurhamidah, 2024), as these elements constitute part of CLS (Tian et al, 2023). Upon completion of this stage, the teacher employs project planning and design assessment tools to assess the students' collaborative efforts. Appendix 2 (https://drive.google.com/file/d/1Y9DnTGjl-QsN9xR4N4-kd_QSlUHWVtkb/view?usp=drive_link) presents the tested aspects and evaluation criteria, while the outcomes of this assessment are analyzed through the pre-observation scores, which reflect students' conceptual comprehension.

Next, at the project implementation stage, students in groups prepare the necessary tools and materials and carry out the steps or procedures outlined in the design. Collaboration among students in groups also needs to be developed in this Chem-PjBL-L-NTT-W stage. In addition, students need to be meticulous in making observations, precise in analyzing data, and interpreting it. This stage includes methods to cultivate or strengthen students' interest in both chemistry theory and laboratory work, which are part of ATCL (Cheung, 2009). This activity is assessed using a project implementation observation sheet and analyzed as post-observation score 1. Subsequently, students analyze the project implementation results and report them in written form individually, and then collaborate again to communicate the project investigation results in groups. Individual student reports and group project communication are then assessed using the project report assessment instrument and analyzed to obtain post-observation score 2. The instruments used at the implementation and reporting stages are not included in this writing due to space limitations, but can be found in Tinenti (2018). Aspects of ATCL, such as having confidence in chemistry learning evaluation and a tendency to study chemistry, are also taught in the stages of Chem-PjBL-L-NTT-W (Cheung, 2011).

The research results show that the treatment at each stage of Chem-PjBL-L-NTT-W affects students' understanding of chemistry concepts. It is worth noting that students' conceptual understanding increases when the learning process involves collaboration and teacher guidance, as observed in the planning and design stages leading to implementation (from pre-observation to post-observation 1). Conceptual understanding then decreases again when collaboration and teacher guidance diminish in the learning activities (especially for TTS and TTU regencies), as observed during the transition from the implementation to the reporting stages (from post-observation 1 to post-observation 2). This suggests that the cognitive skills involved in science process skills are crucial in learning, particularly when solving chemistry problems. This understanding of chemistry concepts is part of the development of social skills that can be acquired through collaborative learning (Eymur & Geban, 2017; Heeg et al., 2020).

Additionally, group discussions and dialogues in a collaborative atmosphere help students build and refine their understanding of chemical concepts. This interaction encourages the development of sociochemical norms that guide students in reasoning and explaining chemical phenomena (Warfa et al, 2018). In relation to CLS, several key points from this research can be highlighted. Statistically, the implementation of Chem-PjBL-L-NTT-W has an impact on students' CLS in all schools. Descriptively and quantitatively, high school students in three regencies show a tendency to decrease their scores in the aspects of communication and collaboration, especially in I3, "I persuade others when I disagree with them." This gives a negative connotation to students' perceptions (most notably among those from the TTS regency). The use of the word "persuade." This means that students think that when there is a difference of opinion with others, they only need to "persuade" (as something biased, not supported by facts, without valid evidence, and not accountable) so that others can agree. The results of the interviews support this, confirming it. The majority of the interviewed students attempted to use valid and logical evidence to convince others that their ideas or opinions need to be considered for acceptance.

Furthermore, the research results on high school students in the TTU and Belu regencies indicate a slight increase in disagreement on most items, and the neutral category remains dominant. The Chem-PjBL-L-NTT-W steps, which are considered new by all interviewed students and teachers, and the obstacles experienced in collaboration and communication can be indicated as the cause of this trend. Therefore, the approach in chemistry learning that accommodates the principles of collaboration and communication among students, such as Chem-PjBL-L-NTT-W, needs to be continuously implemented. If students are accustomed to working in groups, they will also become accustomed to finding the best ways to combine different ideas and knowledge with the aim of achieving better learning outcomes and can teach problem-solving skills as an important learning skill (Stasser & Abele, 2020).

Statistically, the implementation of Chem-PjBL-L-NTT-W affects the ATCL of high school students in TTS and TTU regencies, but not in Belu. However, descriptively and quantitatively, there is a significant increase in the perception of ATCL among high school students in TTS regency, and a low increase in TTU and Belu. This shows that the implementation of Chem-PjBL-L-NTT-W, which involves stages of investigation into the chemical aspects of local wisdom closely related to students' daily lives, also encourages active student participation. This contributes to the improvement of students' attitudes towards learning (Adeoye, 2020; Nzomo et al, 2023).

The following finding is that, before treatment, high school students in TTU and Belu regencies already had a good ATCL. If viewed from a geographical perspective, both high schools are located in the center of the regency capital, with adequate facilities and infrastructure, including laboratories. This becomes one of the key factors in determining students' positive attitudes towards chemistry learning (Tadura, 2024). Adequate laboratory facilities make it easier for teachers to conduct laboratory experiments during chemistry learning before the implementation of Chem-PjBL-L-NTT-W. Supported by interview data indicating that students indeed enjoy learning chemistry through experiments, it can be said that this is one of the factors that has improved the ATCL of students in both schools prior to the implementation of Chem-PjBL-L-NTT-W.

Unlike TTS, the ATCL of students before the treatment was relatively low and increased drastically after the treatment. The school located in the TTS regency is a high school situated on the outskirts of the regency city, with inadequate facilities and infrastructure, including the laboratory. This makes it difficult for teachers to conduct experimental learning activities. Therefore, the implementation of Chem-PjBL-L-NTT-W on the topic of factors affecting chemical equilibrium based on local wisdom, by providing experimental activities using equipment from the students' surroundings, has significantly improved ATCL. Although students showed high enthusiasm for this learning, the implementation of the model faced significant constraints, including limited time allocation and the need for careful lesson planning. Therefore, the implementation of Chem-PjBL-L-NTT-W is recommended to be adjusted to the geographical conditions and school infrastructure, supported by time flexibility through additional learning hours or extracurricular activities, and the need for special regulations regarding teacher workload, given the characteristics of project-based learning models that demand more complex planning, implementation, and assessment processes than conventional approaches.

Related limitations and future research opportunities can be stated as follows: Generalization of the research results needs to be done with caution, even though the implementation of Chem-PjBL-L-NTT-W has been carried out in three schools with different geographical locations and conditions. This is because the sample in this study is not yet representative of the population. Future research is recommended to use a larger and more representative sample that covers a broader population. In this case, it is necessary to involve participants from other regencies with more diverse geographical backgrounds. Chem-PjBL-L-NTT-W can also be adapted to other local wisdom as a context for certain learning materials.

CONCLUSION

The results showed that the implementation strategy of the Chem-PjBL-L-NTT-W model was carried out through the identification and integration of the characteristics of chemistry materials with NTT local wisdom, along with the determination of three project themes for each learning material. The implementation of this model has a significant effect on CLS and ATCL, with variations in effects based on the school context. The effect on CLS was strong for senior high school students in the TTS regency, moderate in the Belu regency, and statistically significant but with a very small effect in the TTU regency. Regarding the ATCL aspect, there was a significant and strong effect in TTS, but the practical improvement was relatively minimal. In contrast, in Belu, the effect was very small and inconsistent. Students' concept comprehension in all three regencies showed significant improvement, with a range of confidence intervals indicating meaningful practical effects. Based on the findings of this study, it is also expected to contribute to innovation in learning chemistry that is more contextual and meaningful through the integration of NTT local wisdom. Thus, it can foster students' logical thinking skills, creativity, and concept comprehension. These findings can also serve as a reference for the preparation of educational policies that prioritize local cultural values as part of a holistic learning process.

ACKNOWLEDGEMENTS

The authors express gratitude to The Directorate of Research, Technology, and Community Service (DRTPM) of the Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia (Kemendikbudristek RI) for funding this research (Number of contract funding letter: 117/E5/PG.02.00.PL/2024, June 11, 2024), Lembaga Penelitian dan Pengabdian Masyarakat (LPPM) of Widya Mandira Catholic University (UNWIRA) Kupang for facilitating this research, and the principal who has given permission, as well as the teachers and students involved in the research

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