JPPIPA 12(7) (2026)

Jurnal Penelitian Pendidikan IPA

http://jppipa.unram.ac.id/index.php/jppipa/index

Implementing the INTER-SETS Learning Model in Acid–Base Chemistry to Improve Students' Science Process Skills and Scientific Attitudes

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Received: May 26, 2026
Revised: June 17, 2026
Accepted: July 25, 2026
Published: July 31, 2026

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DOI: 10.29303/jppipa.v12i7.15434

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Abstract: This study examined whether students' science process skills (SP) and scientific attitudes (SA) changed following the implementation of the INTER-SETS learning model in acid–base chemistry. A pre-experimental one-group pretest–posttest design involving 34 senior high school students was employed. Science process skills were measured using an essay test, whereas scientific attitudes were assessed using a validated questionnaire. Data were analyzed using one-sample Hotelling's T^2 based on difference scores (posttest–pretest), followed by univariate analyses at a significance level of 0.05. The results revealed statistically significant simultaneous improvements in SP and SA after implementing the INTER-SETS learning model (Hotelling's Trace = 11.37, $F(2, 28) = 159.24$, $p < 0.001$). Follow-up analyses also showed significant improvements in science process skills ($F(1, 29) = 197.42$, $p < 0.001$) and scientific attitudes ($F(1, 29) = 57.80$, $p < 0.001$). These findings suggest that integrating guided inquiry with Science, Environment, Technology, and Society (SETS) contexts provides meaningful learning experiences associated with improvements in students' scientific competencies and attitudes during acid–based learning. However, because this study employed a one-group pretest–posttest design, the findings should be interpreted as evidence of improvement rather than definitive causal effects.

Keywords: Contextual learning; Guided inquiry; Inquiry-based learning; Secondary chemistry education; SETS approach

Introduction

Contemporary chemistry education is expected not only to promote conceptual understanding but also to develop scientific competencies required for addressing increasingly complex real-world problems. Rapid scientific and technological advances demand learning environments that foster inquiry, critical thinking, and evidence-based decision making (Benek & Akcay, 2022; Garay & Quintana, 2019). Nevertheless, several studies have reported that Indonesian students continue to demonstrate relatively low levels of twenty-first century scientific competencies (Ichsan et al., 2023; Ilwandri et al., 2023; Srirahmawati et al., 2023). In contemporary science education, these competencies are closely associated with scientific literacy, which involves the ability to explain scientific phenomena, evaluate scientific evidence, and apply scientific knowledge to real-world situations. Therefore, developing science process skills and scientific attitudes is essential to prepare students for informed decision-making in scientific and societal contexts (Azzahra et al., 2024; Gizaw & Sota, 2023; Juhji & Nuangchalerm, 2020; Mulyeni et al., 2019).

Science process skills represent the cognitive and practical abilities required during scientific investigations, whereas scientific attitudes reflect students' curiosity, objectivity, honesty, responsibility, and willingness to evaluate evidence critically (Mushani, 2021; Padilla et al., 1983). These competencies

How to Cite:
Syuhada, F. A., Rohaeti, E., Sutrisno, H., & Zubair, S. (2026). Implementing the INTER-SETS Learning Model in Acid–Base Chemistry to Improve Students' Science Process Skills and Scientific Attitudes. *Jurnal Penelitian Pendidikan IPA*, *12*(7), 58–65. https://doi.org/10.29303/jppipa.v12i7.15434

constitute essential components of scientific literacy and are increasingly emphasized in contemporary science education because they support students in understanding scientific concepts through authentic inquiry rather than memorization.

Despite their importance, previous studies indicate that students' science process skills and scientific attitudes remain insufficiently developed because chemistry instruction is still largely teacher-centered and emphasizes algorithmic problem solving rather than scientific investigation (Akpan et al., 2020; Amaliyah et al., 2024; Hasanah et al., 2020; Hunter, 2015; Sandika & Fitrihidajati, 2018; Sunyono, 2018; Tanti et al., 2020). Consequently, students have limited opportunities to formulate hypotheses, conduct investigations, interpret evidence, and communicate scientific explanations.

Acid–base chemistry provides an appropriate context for developing these competencies because it combines abstract concepts with numerous real-life applications (Kriswantoro et al., 2025). However, classroom instruction frequently focuses on mathematical calculations of pH and pOH as well as memorization of acid–base theories, leaving limited opportunities for students to investigate natural indicators, analyze environmental acidity, interpret titration data, or evaluate the impact of acidic and alkaline substances in everyday life (Agustina et al., 2020; Epinur et al., 2024; Priyambodo et al., 2021). Consequently, the inquiry potential of acid–base chemistry is often underutilized.

Guided inquiry learning has consistently demonstrated positive effects on students' conceptual understanding and science process skills because it actively engages learners in scientific investigations (Adauyah & Aznam, 2024; Gholam, 2019; Orosz et al., 2023; Purwandari et al., 2022; Qablan et al., 2024). However, inquiry activities are often implemented without sufficiently connecting scientific investigations to authentic environmental, technological, and societal contexts. Conversely, the SETS approach effectively contextualizes scientific concepts but does not explicitly organize students' investigative processes (Inthaud et al., 2019; Yörük et al., 2010; Yulianti & Herpratiwi, 2024). These complementary strengths indicate the need for an integrated instructional model.

The INTER-SETS (Integrated Inquiry–Science, Environment, Technology, and Society) learning model was therefore developed by systematically integrating the instructional stages of guided inquiry with the contextual principles of the SETS approach within a single learning framework. Unlike previous studies that have examined guided inquiry and SETS separately, the INTER-SETS model combines scientific investigation with contextual problem solving to encourage students to construct scientific knowledge while simultaneously relating chemistry concepts to environmental, technological, and societal issues.

Considering the need for contextual inquiry-oriented chemistry instruction, this study investigated students' science process skills and scientific attitudes before and after the implementation of the INTER-SETS learning model in acid–base chemistry. Rather than comparing instructional models, this study provides preliminary empirical evidence regarding learning outcomes associated with the implementation of the proposed instructional model.

Method

Research Design

This study employed a pre-experimental research design using a one-group pretest–posttest design. The implementation of the INTER-SETS learning model involved a single class without a comparison group. The study was conducted over a two-month period, from December 2025 to January 2026, and included both classroom instruction and laboratory activities. Students' science process skills (SP) and scientific attitudes (SA) were measured before and after the intervention. The overall research procedure is presented in Figure 1.

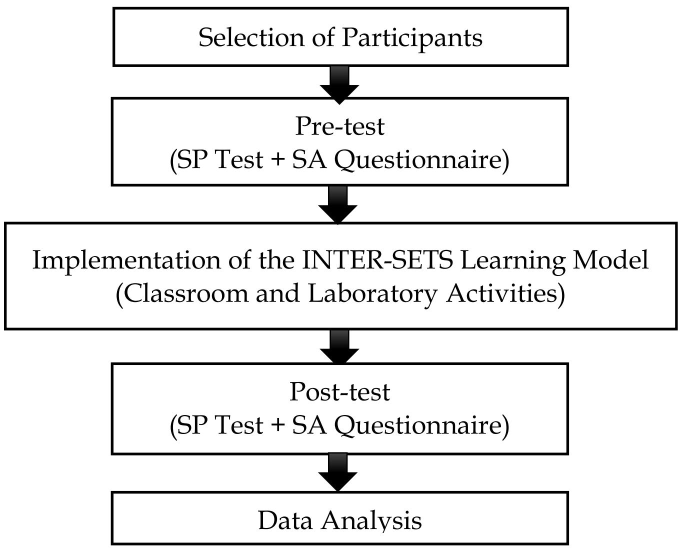

Figure 1. Research procedure

The research participants consisted of 34 eleventh-grade students from a public senior high school in Sleman Regency, Yogyakarta, Indonesia. The participants included 10 male and 24 female students, aged 16–17 years. The school was selected using convenience sampling, and the class was selected through random sampling.

Data Collection Instrument and Data Analysis

The research instruments consisted of SP and SA measures constructed by the researchers to align with the goals of the INTER-SETS. Prior to implementation, both instruments were evaluated through expert judgment to determine their content validity and reliability. The content validity analysis indicated that the science process skills instrument achieved an Aiken's V coefficient of 0.99, reflecting very high validity, whereas the scientific attitudes instrument attained an Aiken's V coefficient of 0.96, classified within the very high validity category (Penfield & Giacobbi, 2004). These results suggest that all instrument items were considered highly suitable and relevant for assessing the targeted constructs. The inter-rater reliability evaluation results based on the Intraclass Correlation Coefficient (ICC) showed that the science process skills instrument obtained a coefficient of 0.83, while the scientific attitudes instrument achieved a coefficient of 0.80, with both instruments meeting the criteria for good reliability (Koo & Li, 2016). Furthermore, Cronbach's alpha coefficients indicated satisfactory reliability for both instruments, with the science process skills instrument demonstrating a coefficient of 0.79, categorized as high reliability, while the scientific attitudes measure obtained a coefficient of 0.93, reflecting very strong reliability (Hair et al., 2010). The outcomes indicate that both instruments were feasible and reliable tools for measuring students' SP and SA within chemistry learning contexts.

Upon completion of the expert review process, empirical evaluation of the measurement tool was performed using Rasch model analysis. The assessment consisted of eight essay-based items aimed at evaluating learners' scientific process abilities during chemistry instruction. The Rasch analysis evaluated several measurement aspects, including person fit (outlier detection), construct validity through unidimensionality analysis, item fit, item difficulty level, and both item and person reliability. The findings indicated that all items satisfied the required measurement criteria, indicating that the instrument was appropriate and dependable for evaluating students' SP.

The scientific attitudes questionnaire was validated in a separate instrument development phase involving 131 senior high school students who were not included in the main intervention study. Following the validation process, the final instrument consisted of 18 items, yielding a participant-to-item ratio of approximately 7:1, which satisfies the recommended sample size for factor analysis (Hair et al., 2019). Prior to conducting Exploratory Factor Analysis (EFA), the suitability of the data for factor analysis was evaluated using the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity (Pusbelina & Sutrisno, 2025). The KMO value was 0.67, indicating acceptable sampling adequacy for factor analysis, while Bartlett's test of sphericity was statistically significant (χ^2 = 1198.44, df = 465.00, $p < 0.001$), confirming that the correlation matrix was appropriate for factor analysis. Construct validity was subsequently examined through EFA using JASP. The factor structure identified by the EFA was then confirmed using Confirmatory Factor Analysis (CFA) in AMOS with the Maximum Likelihood estimation method. Prior to CFA, the data were screened for univariate and multivariate normality as well as the presence of multivariate outliers, and all assumptions required for Maximum Likelihood estimation were satisfied. The CFA results demonstrated satisfactory construct validity, with all standardized loading factor (SLF) values exceeding 0.50 (Hair et al., 2019). Therefore, the scientific attitudes questionnaire was considered valid and appropriate for measuring students' scientific attitudes in chemistry learning.

The research data were analyzed using Hotelling's T^2 test to examine the simultaneous differences in students' science process skills and scientific attitudes before and after the implementation of the INTER-SETS learning model. Prior to the analysis, the assumptions for multivariate analysis were evaluated, including univariate and multivariate normality, the absence of multivariate outliers, and the homogeneity of the variance–covariance matrices, to ensure the appropriateness of Hotelling's T^2 analysis (Stevens, 2009; Sutrisno & Purtadi, 2025). All statistical analyses were conducted using a significance level of 0.05.

Result and Discussion

Prior to the Hotelling's T^2 analysis, several assumption tests were conducted to ensure the suitability of the data for multivariate analysis. Univariate outliers were identified using boxplot inspection. Four outliers were detected in the scientific attitudes scores from the initial sample of 34 students and were excluded from further analysis. Consequently, the final sample consisted of 30 students. Multivariate outliers were subsequently examined using the Mahalanobis distance criterion, and no additional multivariate outliers were identified. Furthermore, tests of multivariate normality, linearity, multicollinearity, and the absence of singularity indicated that the data satisfied the assumptions required for Hotelling's T^2 analysis.

Following the assumption tests, difference scores were calculated by subtracting the pretest scores from the posttest scores for each dependent variable ($SP\_diff = SP\_post - SP\_pre$; $SA\_diff = SA\_post - SA\_pre$). These difference scores were subsequently analyzed using one-sample Hotelling's T^2 to determine whether the combined mean change in science process skills and scientific attitudes differed significantly from zero (Table 1).

Table 1. Descriptive statistics of the difference scores

	Mean	Std. deviation	N
SP_diff	41.04	15.99	30
SA_diff	4.89	3.52	30

Table 1 presents the descriptive statistics of the difference scores (posttest minus pretest) for the two dependent variables. On average, students' science process skills increased by 41.04 points (SD = 15.99), whereas scientific attitudes increased by 4.89 points (SD = 3.52) following the implementation of the INTER-SETS learning model. These positive mean difference scores indicate improvements in both variables after the intervention.

Table 2. One-sample Hotelling's T^2 results based on difference scores

Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	0.92	159.24[b]	2.00	28.00	0.00
	Wilks' Lambda	0.08	159.24[b]	2.00	28.00	0.00
	Hotelling's Trace	11.37	159.24[b]	2.00	28.00	0.00
	Roy's Largest Root	11.37	159.24[b]	2.00	28.00	0.00

The multivariate analysis demonstrated that students' science process skills (SP) and scientific attitudes (SA) changed significantly following the implementation of the INTER-SETS learning model. The one-sample Hotelling's T^2 analysis based on the difference scores revealed a statistically significant multivariate effect (Hotelling's Trace = 11.37, $F(2, 28) = 159.24$, $p < 0.001$), indicating that the combined mean changes in SP and SA differed significantly from zero. These findings suggest that students experienced simultaneous improvements in both competencies after participating in the INTER-SETS learning activities. However, considering that this study employed a one-group pretest–posttest design without a comparison group, these findings should be interpreted as evidence of significant improvement associated with the implementation of the learning model rather than definitive causal effects.

Follow-up univariate analyses indicated that both dependent variables exhibited statistically significant improvements after the implementation of the INTER-SETS learning model (Table 3). The analysis yielded $F(1,29) = 197.42$ ($p < 0.001$) for science process skills and $F(1, 29) = 57.80$ ($p < 0.001$) for scientific attitudes. These findings indicate that the observed increases occurred consistently across both variables, suggesting that the learning activities supported students in developing scientific inquiry skills alongside positive scientific attitudes.

Table 3. Tests of between-subjects effects

Source	Dependent variable	Type III sum of squares	df	Mean square	F	Sig.
Corrected Model	SP_diff	0.00[a]	0			
	SA_diff	0.00[a]	0			
Intercept	SP_diff	50532.55	1	50532.55	197.42	0.00
	SA_diff	717.07	1	717.07	57.80	0.00
Error	SP_diff	7422.93	29	255.96		
	SA_diff	359.74	29	12.40		
Total	SP_diff	57955.48	30			
	SA_diff	1076.81	30			
Corrected Total	SP_diff	7422.93	29			
	SA_diff	359.74	29			

The improvement in science process skills can be explained by the inquiry-oriented characteristics embedded in the INTER-SETS learning model. Throughout the learning process, students actively observed acid–base phenomena, formulated hypotheses, designed and conducted experiments, interpreted experimental evidence, and communicated scientific findings. These inquiry activities provided authentic opportunities for students to practice the core components of science process skills instead of merely receiving conceptual explanations from the teacher (Purtadi et al., 2023; Tonapa & Atun, 2024). Previous studies have similarly reported that inquiry-based chemistry instruction promotes students' ability to investigate scientific problems and construct conceptual understanding through direct experience (Gumilar & Wardani, 2020; Oetpah et al., 2024; Pan et al., 2021).

The improvement in scientific attitudes may be attributed to the integration of the SETS perspective within the inquiry process. Rather than learning acid–base concepts solely through formulas and calculations, students explored authentic environmental and societal issues, discussed alternative solutions, and evaluated the implications of scientific knowledge for everyday life. Such learning experiences encourage curiosity, responsibility, open-mindedness, cooperation, and evidence-based reasoning, which are recognized as essential dimensions of scientific attitudes (Akcay & Akcay, 2015; Buhera et al., 2024; Sa'adah et al., 2024).

The findings also support the theoretical rationale underlying the development of the INTER-SETS learning model. Unlike conventional guided inquiry, which primarily emphasizes scientific investigation, the INTER-SETS model systematically integrates inquiry activities with Science, Environment, Technology, and Society (SETS) contexts. This integration allows students not only to investigate scientific phenomena but also to connect acid–base concepts with environmental issues, technological applications, and societal problems. Consequently, students develop scientific knowledge through contextual experiences that enhance both cognitive and affective aspects of learning.

These findings are also consistent with Vygotsky's social constructivist perspective, which emphasizes that knowledge is constructed through social interaction and meaningful experiences. During the implementation of the INTER-SETS learning model, students collaboratively discussed scientific problems, conducted laboratory investigations, exchanged ideas, and reflected on experimental findings. Such collaborative inquiry enables learners to construct conceptual understanding while simultaneously developing positive scientific attitudes through interaction with peers and teachers (Nguyen et al., 2025; Onn & Im, 2026; Slavin, 2000).

The present findings are consistent with previous studies reporting that inquiry-oriented and contextual science learning environments facilitate improvements in students' science process skills and scientific attitudes (Aulia & Asih, 2020; Pulungan et al., 2021; Supornpanitkul et al., 2025). However, the current study extends previous work by implementing an integrated INTER-SETS learning model that combines guided inquiry with SETS-oriented learning within acid–base chemistry instruction. This integrated approach provides students with opportunities to investigate scientific phenomena while simultaneously connecting chemistry concepts to environmental, technological, and societal contexts.

Despite these encouraging findings, several limitations should be acknowledged. The study employed a pre-experimental one-group pretest–posttest design without a comparison group. Consequently, the observed improvements cannot be attributed exclusively to the INTER-SETS learning model because other uncontrolled factors may also have influenced students' performance. Future studies employing quasi-experimental or randomized controlled designs with larger samples are recommended to provide stronger evidence regarding the effectiveness of the INTER-SETS learning model.

Conclusion

This study demonstrated significant improvements in students' science process skills (SP) and scientific attitudes (SA) following the implementation of the INTER-SETS learning model in acid–base chemistry learning. The multivariate and follow-up univariate analyses indicated that both variables improved significantly from pretest to posttest, suggesting that the learning experiences provided through the integration of guided inquiry and Science, Environment, Technology, and Society (SETS) contexts were associated with positive learning outcomes. By engaging students in contextual scientific investigations, experimentation, discussion, and real-world problem solving, the INTER-SETS learning model supports the development of scientific competencies alongside positive scientific attitudes. These findings suggest that the INTER-SETS learning model represents a promising instructional alternative for promoting meaningful chemistry learning, particularly in topics that can be connected to environmental, technological, and societal issues. Nevertheless, because this study employed a pre-experimental one-group pretest–posttest design without a comparison group, the observed improvements should not be interpreted as definitive causal effects of the intervention. Future studies using quasi-experimental or randomized controlled designs with larger and more diverse samples are recommended to provide stronger evidence regarding the effectiveness and generalizability of the INTER-SETS learning model.

Acknowledgments

Our gratitude goes to the Chemistry Education Department, Faculty of Mathematics and Natural Sciences, Yogyakarta State University for support in publishing this article.

Author Contributions

Conceptualization was carried out by F.A.S. and E.R.; methodology was developed by F.A.S.; software was managed by H.S.; validation was conducted by F.A.S., E.R., and H.S.; formal analysis was performed by H.S.; investigation was undertaken by S.Z.; resources were provided by E.R.; data curation was handled by H.S.; writing—original draft preparation was completed by F.A.S.; writing—review and editing were carried out by E.R.; visualization was prepared by S.Z.; supervision was provided by H.S.; project administration was managed by S.Z.; and funding acquisition was secured by E.R. All authors have read and agreed to the published version of the manuscript.

Funding
This research was funded by Ministry of Higher Education, Science, and Technology year 2026 via scheme Doctoral Dissertation Research (Penelitian Disertasi Doktor) with no. Contract 249/C3/DT.05.00/PL-Baru/2026 and 231.4/DST/UN34.9/T/PT.01.03/2026

Conflicts of Interest
The authors declare no conflict of interest.

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