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Comparing Titration Practices in Educational Institutions with Varied Accreditation Levels

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ABSTRACT

Purpose of the study: The study aims to compare the titration practices and the student-to-burette ratio among institutions with varied accreditation levels in Albay, Philippines.

Methodology: The descriptive survey compared titration practices and student-to-burette ratio across educational institutions stratified with varied accreditation levels. The population was Chemistry Instructors and Laboratory Custodians from 15 institutions, totalling 30 respondents, with a sample size of 24 respondents. Data was collected using Survey Instruments for Chemistry Instructors and Laboratory Custodians. Statistical analysis included descriptive and inferential statistical analysis with a chi-square test of association and Cramer's V effect size ($\alpha = 0.05$).

Main Findings: Associations between accreditation level, conduct, and availability of reagents for neutralization and complexometric titrations, chi-square test of association, and Cramer's V effect size (α 0.05) were found. The student-to-burette ratio ranged from 1 to 4 students (Level IV and III) and 40+ students (II and I) per acid and base burettes to no burettes in Level I institutions. The reasons for the non-performance of the titration activities were: lack of materials, training, and experience, assistance in the laboratory, and class size.

Novelty/Originality of this study: This study examines how accreditation levels and titration resources are associated with titration education. The challenges and strengths of titration education in Albay, Philippines, might not be captured in national and international studies. The holistic approach of evaluating titration practices, resource availability, and student-to-burette ratio provides a comprehensive picture of titration education in the province.

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1. INTRODUCTION

The importance of evidence-based teaching laboratories in chemistry education justifies the investment in teaching laboratories, especially when faced with alternative pedagogies like virtual labs and simulations. The call is for scientific rigor in supporting claims about student learning [1]. Analytical chemistry is responsible for characterizing the composition of matter, both qualitatively (what is present) and quantitatively (how much is present) [2]. A typical quantitative analysis starts with choosing a method; there are four quantitative analytical methods used in quantitative analysis. The four methods are gravimetric, volumetric, electroanalytical, and spectroscopic. The volumetric method measures the volume of a solution containing sufficient reagent to react completely with the analyte [3]. Volumetric analyses are quantitative analytical techniques that employ titration in comparing an unknown with a standard.

In a titration, a sample solution of known volume (sample) containing a substance to be determined (analyte) of unknown concentration is gradually mixed with a measured and controlled volume of a standardized solution. The titration continues until stoichiometric completion or equivalence point [4]. Like any quantitative analysis, the solutions must be standardized, instruments calibrated, and the result must be evaluated for its reliability.

The four (4) main types of titration conducted in a science laboratory are neutralization, REDOX, precipitation, and complexometric titrations [2]. Understanding the types of titration guides the students on the presence of fake vinegars (petroleum-based acetate) in grocery and sari-sari stores, as reported by the Head of the Philippine Nuclear Research Institute (PNRI), Nuclear Analytical Techniques Application Sections, that may cause serious health problems [5]. REDOX titration could identify the used oils of street vendors with Peroxide Value (POV) from 33.33 – 86.67 meq/kg, while the recommended value of the Food and Drug Administration (FDA) is 10 meq/kg [6]. Highly oxidized oils can cause food poisoning, neurotoxicity, and cancer. With precipitation titration, the measurement of salt content of commonly eaten food and drinks with dietary sodium between 3,898 mg and 4,344 mg, or 10.4 g of salt per day. The recommended amount of the World Health Organization (WHO) is only 2,000 mg or 5.0 g per day [7]. The risk of cardiovascular and kidney diseases is possible when Filipinos are unaware of the salt content of food and drinks in school canteens and other eating outlets. The water hardness level in water systems near calcium or magnesium-enriched areas can be measured by complexometric titration. Increased water hardness along the coastal areas of Las Piñas City and Parañaque City caused massive fish kills last 2019 [8]. These activities are mandated in the subject description of Analytical Chemistry for the BSEd major in science.

The Commission on Higher Education, through CHED Memorandum Order No. 75 s. 2017, prescribed the calibration of instruments, volumetric, and gravimetric methods, especially those analyses encountered in industries in analytical chemistry for a Bachelor's in Secondary Education (BSEd) major in science. The compliance of educational institutions with the subject description of analytical chemistry for BSEd science majors is dependent on the availability of a titration setup. Conceptual understanding and process skills in chemistry are nurtured and fostered through scientific inquiry and critical thinking during practical laboratory activities [9]-[12].

Budget constraints in public universities and community colleges, and the high tuition and laboratory fees in private colleges and universities, which cause fewer enrollees, may affect the availability of titration equipment or materials. Therefore, titration activities in these institutions may vary due to the unavailability or lack of equipment. The possible gaps in laboratory supplies and educational performance were identified considering the differences in the titration activities performed and the available number of titration equipment/materials in the different educational institutions.

The Province of Albay comprises three (3) Districts with colleges and universities offering Analytical Chemistry, BSEd major in science. An interview with the course instructor teaching in a community college revealed the non-functional science laboratory of their college and the absence of laboratory activities on titration. The institutions that participated in the study were accredited by the Philippine Accrediting Association of Schools, Colleges, and Universities (PAASCU), the Philippine Association of Colleges and Universities – Commission on Accreditation (PACU-COA), and the Accrediting Agency of Chartered Colleges and Universities of the Philippines, Inc. (AACCUP).

The levels of accreditation of the BSEd major in science programs were from Level IV to Level I. An institution with Level I and II accreditation can have full administrative and financial deregulation, grants, and funding assistance. Level III will have all the benefits of I and II, with an additional privilege to offer distance education and extension classes. The highest level (IV) will have the benefits of levels I, II, and III and will have full autonomy of the program [13]. The purpose of accreditation in the Philippines is to identify Centers of Excellence (COE) and Centers of Development (COD), for funding from the Commission of Higher Education (CHED), autonomy and deregulation, and prestige. It can be observed that all accrediting bodies have Area Five (V) as Laboratories to ensure adequate, up-to-date, well-maintained, and safe laboratories to support the functions of the teaching-learning process, research, and community service [12].

Previous studies suggested that accreditation can improve the quality of higher education by refining the policies, processes, and core functional areas like research, academics, and teaching-learning [13]. The effect of accreditation on schools in terms of open system elements as an alternative to the formal school system showed improvement in its policies and operation [14]. This study compared the titration practices and student-to-burette ratio among different educational institutions with varied accreditation levels to establish the need for an improvised titration kit (ITK) for resource-constrained educational institutions. The data from the analytical chemistry instructor and laboratory custodian provided the complete profile of titration activities conducted in Albay, Philippines. Despite the established policies and accreditation standards, the practical implications of these frameworks on the day-to-day implementation of laboratory activities like titration, and the resulting resource availability for students, remain underexplored, especially concerning the differences between institutions with different accreditation statuses in Albay

2. RESEARCH METHOD

2.1. Types of Research

The research employed a quantitative design, specifically using the Chi-square test of independence. This design was chosen to assess the relationship between the accreditation levels of institutions and their titration practices. The hypothesis tested was whether there is an association between these two variables [15].

2.2. Population and Research Sample

The study focused on Analytical Chemistry Instructors and Laboratory Custodians from 15 institutions in Albay, Philippines. The total population comprised 30 respondents, with a calculated sample size of 24 respondents derived from Cochran's sample formula, considering an alpha level of 0.05 and an anticipated return rate of 80% [16].

2.3. Data Collection Technique

The survey was the data collection technique used in the study. The definition of survey research is "the collection of information from a sample of individuals through their responses to questions" [17]. Structured questionnaire for analytical chemistry instructors revealed the titration activities conducted, the average number of students enrolled in the subject, and the reasons for not conducting the titration activity. A structured questionnaire for laboratory custodians provided the availability of the titration equipment and reagents. The data gathered will be the basis for the development of an improvised titration kit (ITK) and laboratory activities for titration.

2.4. Research Instruments

The research instruments utilized in the study are the survey instrument for the analytical chemistry instructor and the laboratory custodian. The instruments were validated for their reliability using Cronbach's alpha technique in Jamovi 2.4.11. The survey instrument for analytical chemistry instructors and laboratory custodians obtained a reliability coefficient of 0.779 and 0.778, respectively. A value of Cronbach's Alpha from 0.60 to 0.80 is considered moderate and acceptable [18]. The instrument matrix is shown in Table 1. Along with the questionnaire is the consent form signed by the analytical chemistry instructor and laboratory custodian. The accreditation level of the institution was included in the questionnaires.

2.5. Data Analysis Techniques

The data analysis techniques utilized were descriptive and inferential statistics. The accreditation level of the institutions was categorized into Level I, II, III, & IV as granted by the accrediting agencies PAASCU, PACU-COA, and AACCUP. The titration practices were categorized as conducted and not conducted. The availability of equipment was categorized as available and not available. The availability of reagents was categorized as available (complete), incomplete, and not available. If the reagent is available but not enough for the size of the students in class, it is considered incomplete. When one of the reagents was coded incomplete, the type of titration was categorized as incomplete. The average number of students per class was taken from the survey instrument for analytical chemistry instructors. The Chi-square of independence was employed to analyze the relationship between the categorical variables. A high Chi-square value indicates a potential association between the categorical variables, and a $p < .05$ suggests a significant association between the categorical variables [17]. To test the effect size, Cramer's V was utilized to show how strong the relationship of the variables appears to be. Table 2 shows the interpretation of the effect size [19]. All statistical analyses were conducted in Jamovi 2.4.11 [20].

2.6. Flow Chart of Research Procedure

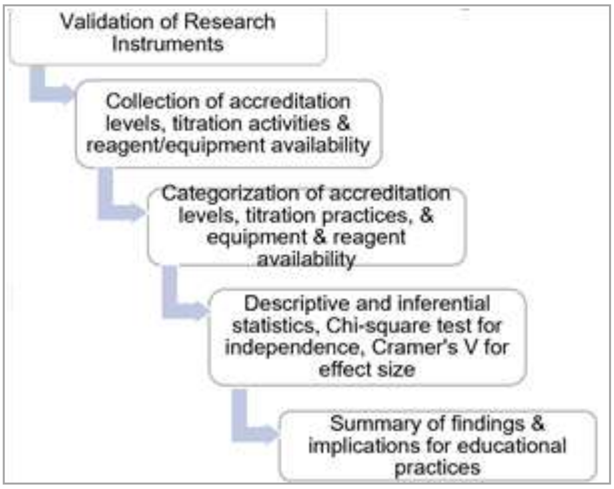

Figure 1. Research Flow Chart

Table 1. Instrument Matrix

Respondent	Titration Activity	Conducted (Yes/No)	Reason (if No)
Analytical Chemistry Instructor	1. Titration between a strong acid and a strong base		
	2. Titration between a strong acid and a weak base		
	3. Titration between a strong base and a weak acid		
	4. Precipitation titration		
	5. REDOX titration		
	6. Complexometric titration		
	7. Others (please specify)		
Laboratory Custodian	Equipment	Available (Yes/No)	Quantity (if Yes)
	1. iron stand		
	2. burette clamp		
	3. acid burette		
	4. base burette		
	5. volumetric flask		
	6. beaker		
	7. Erlenmeyer flask		
	8. graduated cylinder		
	9. dropper		
	10. others (please specify)		
	Reagent	Available (Yes/No)	Quantity (if Yes)
	1. Neutralization titration		
	a. hydrochloric acid or strong acid		
	b. sodium hydroxide or strong base		
	c. potassium hydrogen phthalate or primary standard for base		
	d. methyl orange or primary standard for acid		
	e. acetic acid or weak acid		
	f. ammonia solution or weak base		
	2. Precipitation titration		
	a. silver nitrate		
	b. sodium chloride		
	c. potassium chromate		
	3. Complexometric titration		
	a. manganous sulfate		
	b. eriochrome black T		
	c. sulfuric acid		
	d. sodium hydroxide		

e. sodium azide
f. EDTA
4. REDOX titration
a. potassium iodide
b. chloroform
c. acetic acid
d. starch indicator
e. sodium thiosulfate
5. Others (please specify)

Table 2. The Effect Size

Effect size (ES)	Interpretation
ES ≤ 0.2	The result is weak. Although the result is statistically significant, the fields are only weakly associated.
0.2 < ES ≤ 0.6	The result is moderate. The fields are moderately associated.
ES > 0.6	The result is strong. The fields are strongly associated.

3. RESULTS AND DISCUSSION

3.1 Summary of Findings

3.1.1 Data from the survey instruments for analytical chemistry instructors and laboratory custodians

Based on the survey instruments for analytical chemistry instructors and laboratory custodians, the following data were gathered:

Table 3. Frequency Distribution Table for Participants

Role	Frequency	Percentage
Analytical Chemistry Instructor	12	80
Laboratory Custodian	12	80
Total	24	80

The equal participation of analytical chemistry instructors (n=12) and laboratory custodians (n=12) in this study provides an initial insight into the potential for a balanced 'community of practice' [21] within the laboratory setting. This finding aligns with the structure of science instruction must involve contextual and experiential development through structured activities to fill the gaps in learning [22]. The analytical chemistry instructor can give contextual learning, while the experiential development can be experienced with the help of the laboratory custodians, assisting the instructors during titration activities. However, further analysis of the survey data will be necessary to fully understand the nature and quality of this interaction and its impact on titration activities and resource management. The accreditation level of the institutions where the analytical chemistry instructor and laboratory custodian are assigned is shown in Table 4.

Table 4. Frequency Distribution for Accreditation Levels

Accreditation Level	Frequency	Percentage
Level I	6	50
Level II	2	17
Level III	3	25
Level IV	1	8
Total	12	100

The institution with a Level IV accreditation is the Center for Excellence (COE) in Education in Albay, Philippines. A COE is entitled to priority funding and grants from government agencies like the Commission on Higher Education (CHED) and can enhance the chemistry laboratory of the school [23]. It was observed that all accrediting bodies have Area Five (V) as Laboratories to ensure adequate, up-to-date, well-maintained, and safe laboratories to support the functions of the teaching-learning process, research, and community service [24]. The difference in access to resources between a Level IV and a Level I institution could be described by the resource dependence theory. The theory suggests that organizations' activities are constrained by their access to and control over critical resources [25]. The Level IV had priority funding and would have sufficient laboratory equipment and reagents. Quality dimensions in higher education characterize a high-quality institution as having sufficient equipment, a relevant curriculum, and providing practical and theoretical knowledge [26]. The difference in the distribution of accreditation levels of educational institutions could affect access and equity in educational institutions [27].

Table 5. Reasons for not conducting titration activities

Reasons	Frequency	Percentage
Lack of equipment and reagents	16	53
Limited teacher experience and training	6	20
Class size	4	13
Lack of laboratory assistance	4	13
Total	30	100

Data was collated from the twelve analytical chemistry instructors on why the six titration activities were not conducted, and the responses were grouped into four reasons, as shown in Table 5. The responses were categorized according to the steps: coding of data, searching for themes, refining the themes, and reporting the findings [28]. The categories were lack of equipment and reagents (53%), limited teacher experience and training (20%), class size, and lack of laboratory assistance (20%). The state of science laboratories in the Philippines in 2001 was described as resource-constrained buildings with no equipment for science, art, and other practical subjects [29]. More than half of the analytical chemistry instructors suggested that the science laboratory is not equipped for titration activities. The resource dependence theory suggests that institutions and instructors are directly constrained in conducting practical activities due to a lack of essential resources. This dependence can significantly impact the curriculum and pedagogical choices [25]. The "limited teacher experience and training" reason directly relates to teacher efficacy – an instructor's belief in their ability to teach and manage classroom activities effectively. Lack of training and experience can lower self-efficacy, leading to a reluctance to undertake complex laboratory activities like titrations. A survey conducted by the leading education institution in the country showed that the need for professional training and learning was at the top of the imperatives for in-service teachers [30]. A recent study on profiling the low-frequency science students in the Philippines showed that a small class size, high school standing or accreditation level, and sufficient funding for teacher training were associated with high literacy scores in science in the Programme for International Student Assessment (PISA) [31].

3.1.2 Association between the conduct of titration activities and the level of accreditation of the institutions

The association between the conduct of titration activities and the level of accreditation achieved by the institution is presented in Table 5. Each row represents the observed values as actual counts of Level I to IV accredited institutions that performed or conducted the specific titration activity; expected values represent the values of each cell of the table if there was no association between the conducted titration activity and the level of accreditation. The chi-square value (χ^2) compares the observed values to the expected values and whether the difference is statistically significant [32]. The degrees of freedom (df) were taken from the number of categories minus one; in the study, the categories were the levels of accreditation. A p-value (p) of less than 0.05 indicates the association between the conduct of titration activities and the institution's accreditation level. Cramer's V showed the effect size.

Table 6. Comparison of Conducted and Expected Titration Activities: Chi-Square Test Results and Effect Size (Cramer's V)

Titration Activity	Conducted Activity (Observed Values)	Expected Values	Chi-square Value (χ^2)	Degrees of Freedom (df)	p-value (p)	Cramer's V
Strong acid and strong base	Level IV: 1, Level III: 2, Level II: 3, Level I:1	Level IV: 1, Level III: 1.17, Level II: 2.17, Level I: 3.50	8.57	3	0.036	0.845
Strong base and weak acid	Level IV: 1, Level III: 2, Level II: 3, Level I:1	Level IV: 1, Level III: 1.17, Level II: 2.17, Level I: 3.50	8.57	3	0.036	0.845
Strong acid and weak base	Level IV: 1, Level III: 2, Level II: 3, Level I:1	Level IV: 1, Level III: 1, Level II: 2.00, Level I: 3.00	6.67	3	0.112	0.707
Precipitation titration	Level IV: 1, Level III: 1, Level II: 0,	Level IV: 1, Level III: 0.667, Level	6.00	3	0.154	0.661

	Level I:1	II: 1.667, Level I: 2.000				
Complexometric titration	Level IV: 1, Level III: 1, Level II: 0, Level I: 0	Level IV: 1, Level III: 0.500, Level II: 0.500, Level I: 1.500	9.33	3	0.038	0.839
REDOX titration	Level IV: 0, Level III: 1, Level II: 0, Level I: 0	Level IV: 0.167, Level III: 0.167, Level II: 0.167, Level I: 0.500	3.27	3	0.351	0.522

Table 6 presents a comparison between the observed frequency of conducted titration activities across different accreditation levels and the expected frequencies under the assumption of no association between these two variables. The chi-square (χ^2) test was used to determine if there is a statistically significant association, while Cramer's V was employed to assess the strength of any such association. The results indicate statistically significant associations ($p<0.05$) between the institution's accreditation level and the conduct of strong acid and strong base titration (χ^2) = 8.57, df = 3, p = 0.036, Cramer's V = 0.845) and strong base and weak acid titration (χ^2) = 8.57, df = 3, p = 0.036, Cramer's V = 0.845), as well as complexometric titration (χ^2) = 9.33, df = 3, p = 0.038, Cramer's V = 0.839). The high Cramer's V values (0.845 and 0.839, respectively) suggest a strong association between the accreditation level and the likelihood of these specific titration activities being conducted. For strong acid and weak base titration (χ^2) = 6.67, df = 3, p = 0.112, Cramer's V = 0.707) and precipitation titration (χ^2) = 6.00, df = 3, p = 0.154, Cramer's V = 0.661), the chi-square tests did not yield statistically significant results ($p>0.05$), although the Cramer's V values indicate a moderate to strong association. This suggests a trend, but the observed differences in the conduct of these titrations across accreditation levels might have occurred by chance in this sample.

REDOX titration showed no statistically significant association (χ^2) = 3.27, df = 3, p=0.351) and a relatively lower Cramer's V value (0.522), indicating a weaker relationship with the institution's accreditation level. The finding that neutralization titrations (strong acid-strong base and strong base-weak acid) and complexometric titrations show a strong association with accreditation level may reflect the greater availability of necessary equipment and reagents in higher-accredited institutions, as suggested by the priority funding and enhanced resources associated with Centers of Excellence (COEs) and higher accreditation levels [33]. This aligns with the earlier observation that a lack of equipment and reagents was a primary reason for not conducting titration activities (Table 5). The significant association between accreditation level and the conduct of laboratory activities supports the study, which found a link between students' satisfaction with laboratory services and the institution's accreditation level [29]. Higher accreditation often implies better-equipped and managed laboratories, which likely translates to a greater capacity to offer a wider range of practical activities. The observation that REDOX, complexometric, and precipitation titrations were the least performed activities could be attributed to factors such as the potential need for more specialized equipment or reagents, or perhaps a lack of instructor familiarity or training with these specific techniques, as indicated in Table 5.

3.1.3 Association between the availability of titration equipment and reagents and the level of accreditation of the institutions

Based on the data gathered on the analytical chemistry instructors and laboratory custodians, the following data were gathered.

Table 7 shows the association of the available titration equipment and the accreditation levels of the institutions. The columns are the titration equipment, the observed and expected values of the available equipment, the chi-square value, degrees of freedom, p-value, and the Cramer's V value. The burette clamp, acid burette, graduated cylinder, and dropper had high chi-square values from 2.40 to 6.00, which indicates a more significant deviation between the observed and expected values. The rest of the equipment had lower chi-square values and higher p-values, suggesting a minor deviation or difference between the observed and expected values.

The statistically significant associations might translate into differences in students' hands-on learning experiences and process skills development in analytical chemistry. The results are also linked to the reasons for not conducting titration activities in Table 5 and the distribution of accreditation levels in Table 4. For example, Level I institutions, which reported most resource limitations, also showed the lowest rates of conducting complexometric titration.

While there was no significant association between the availability of equipment and the accreditation level of the institution, it was shown that only two (2) of the six (6) Level I accredited institutions have an acid burette and burette clamp. The data in Table 7 supported the titration activities' non-performance due to the required equipment.

Table 8 shows the titration reagents categorized based on the titration activity they are utilized for, the questionnaire for the laboratory custodian confirmed the availability of the titration reagent, and the estimated amount. When all the required reagents or chemicals are available, the institution is marked complete. If one (1) reagent is not available or an insufficient amount is available based on the number of students enrolled, it is marked incomplete, and if all the reagents or chemicals are not available, the category is not available.

Table 7. Comparison of Available and Not Available Titration Equipment: Chi-Square Test Results and Effect Size (Cramer's V)

Titration Equipment	Available Equipment (Observed Values)	Expected Values	Chi-square Value (χ^2)	Degrees of Freedom (df)	p-value (p)	Cramer's V
Iron stand	Level IV: 1, Level III: 2, Level II: 3, Level I: 4	Level IV: 1.00, Level III: 1.67, Level II: 2.67, Level I: 5.00	2.20	3	0.494	0.192
Burette clamp	Level IV: 1, Level III: 2, Level II: 2, Level I: 2	Level IV: 1.00, Level III: 2.33, Level II: 1.33, Level I: 4.00	6.00	3	0.112	0.707
Base burette	Level IV: 1, Level III: 2, Level II: 1, Level I: 4	Level IV: 1.00, Level III: 1.50, Level II: 1.50, Level I: 4.50	2.22	3	0.528	0.430
Acid burette	Level IV: 1, Level III: 2, Level II: 1, Level I: 1	Level IV: 1.00, Level III: 1.17, Level II: 1.17, Level I: 3.50	4.46	3	0.216	0.609
Volumetric flask	Level IV: 2, Level III: 2, Level II: 1, Level I: 5	Level IV: 1.00, Level III: 1.67, Level II: 1.67, Level I: 5.00	5.45	3	0.141	0.674
Beaker	Level IV: 1, Level III: 2, Level II: 2, Level I: 5	Level IV: 1.00, Level III: 1.83, Level II: 1.83, Level I: 5.50	1.09	3	0.779	0.122
Erlenmeyer flask	Level IV: 1, Level III: 2, Level II: 2, Level I: 5	Level IV: 1.00, Level III: 1.83, Level II: 1.83, Level I: 5.50	1.09	3	0.779	0.122
Graduated cylinder	Level IV: 1, Level III: 2, Level II: 1, Level I: 5	Level IV: 1.00, Level III: 1.67, Level II: 1.67, Level I: 5.00	2.40	3	0.494	0.447
Dropper	Level IV: 1, Level III: 2, Level II: 1, Level I: 5	Level IV: 1.00, Level III: 1.67, Level II: 1.67, Level I: 5.00	2.40	3	0.494	0.192

The reagents needed for complexometric titration had the lowest p-value of 0.007, indicating a significant difference in the observed and expected values. The Cramer's V for reagents required for complexometric titration is 0.500, showing a moderate association between the reagents needed for complexometric titration and accreditation level. Only the Level IV accredited institution had minimal amounts of manganous sulfate, Ethylene diamine tetraacetic acid (EDTA), and Eriochrome Black T for complexometric titration. The reagents needed for neutralization titrations were sufficiently available in the Level IV accredited institutions; it was insufficiently available in the other institutions with Levels III to I accreditation, and not available in three Level 1 accredited institutions. The results verified the comments of the laboratory instructors about not performing the titration activity due to the unavailability of the reagents or chemicals. The availability of laboratory equipment and reagents is an indicator of the compliance of a school with quality assurance. According to Reyes and Pateña [34], area V or laboratories was one challenge their institution encountered during their school's accreditation.

Table 8. Comparison of Available and Not Available Titration Reagents: Chi-Square Test Results and Effect Size (Cramer's V)

Titration Activity	Complete (Observed)	Incomplete (Observed)	Not Available (Observed)	χ^2	df	p-value (p)	Cramer's V
Neutralization	Level IV: 1, Level III: 0, Level II: 0, Level I: 0	Level IV: 0, Level III: 2, Level II: 3, Level I: 3	Level IV: 0, Level III: 0, Level II: 0, Level I: 3	10.3	3	0.103	0.655
Precipitation	Level IV: 1, Level III: 2, Level II: 0, Level I: 0	Level IV: 0, Level III: 0, Level II: 2, Level I: 3	Level IV: 0, Level III: 0, Level II: 1, Level I: 3	12.0	3	0.062	0.707
Complexometric	Level IV: 0, Level III: 0, Level II: 0, Level I: 0	Level IV: 1, Level III: 0, Level II: 1, Level I: 0	Level IV: 0, Level III: 2, Level II: 2, Level I: 6	12.0	3	0.007	0.500
REDOX	Level IV: 1, Level III: 1, Level II: 0, Level I: 0	Level IV: 0, Level III: 1, Level II: 3, Level I: 3	Level IV: 0, Level III: 0, Level II: 0, Level I: 3	12.0	3	0.062	0.677

3.1.4 Quantification of the student-to-burette ratio

From the average number of students population per class and the number of acid and base burettes per institution, the student-to-burette ratio was computed by dividing the number of students by the number of burettes. Example of an institution with Level IV accreditation, the average number of students enrolled per class is thirty (30), and there were fifteen (15) acid burette, therefore, the ratio is 1:2. For the base burette, there were fifteen (15) base burette, therefore the ratio is 1:2.

Table 9. Burette-to-Student Ratios Across Institutional Accreditation Levels

Institution Accreditation Level/Code	Average Number of Students per Class	Acid Burette-to-Student Ratio	Base Burette-to-Student Ratio
Level IV	30	1:2	1:2
Level III/A	7	1:2	1:1
Level III/B	40	1:4	1:1
Level II/A	40	1:40	1:4
Level II/B	13	1:13	1:13
Level II/C	39	1:39	1:5
Level I/A	45	1:23	No burette
Level I/B	15	No burette	No burette
Level I/C	34	No burette	1:7
Level I/D	34	No burette	1:6
Level I/E	15	No burette	1:4
Level I/F	35	No burette	No burette

The data indicate a significant disparity in burette availability relative to class size across the accreditation levels. Institutions with Level IV and Level III accreditation generally exhibit more favorable burette-to-student ratios (ranging from 1:1 to 1:4). This suggests that, on average, there are enough burettes for students to work in small groups of 2 to 4 members, which is often considered ideal for hands-on laboratory activities. In contrast, institutions with Level II accreditation show considerably higher student-to-burette ratios, particularly for acid burettes (ranging from 1:5 to 1:40). This implies that in these institutions, there are significantly fewer burettes available per student. For instance, in one Level II institution, there is only one acid burette for every 40 students. This high ratio likely necessitates alternative teaching methods, such as instructor demonstrations, rather than individual or small-group hands-on practice for all students. The situation is even more pronounced in Level I accredited institutions. A concerning trend is the complete unavailability of acid burettes in four out of six Level I institutions. Furthermore, two Level I institutions also report a complete lack of base burettes. Even in the Level I institutions where burettes are available, the ratios tend to be quite high (e.g., 1:6, 1:7, 1:23), indicating limited access for students.

The ideal burette-to-student ratios observed in Level IV and some Level III institutions likely facilitate effective group work (2-4 students per group), allowing for direct engagement with the titration process. However, the less favorable ratios in Level II institutions strongly suggest that many students may not have the opportunity for hands-on practice and might primarily learn through instructor demonstrations. The complete or near-unavailability of burettes in Level I institutions raises serious concerns about the students' ability to grasp the fundamental concepts of titrations that rely on these pieces of equipment. Without the opportunity to manipulate the burettes and observe the titration process firsthand, their understanding may be limited to theoretical knowledge. This lack of practical experience can hinder the development of essential process skills in the chemistry laboratory. The development of process skills in the chemistry laboratory was proven when students were allowed to conduct laboratory activities and write laboratory reports that supported the concepts learned in the lecture [9].

The study does not represent the status of titration education in the country, but was conducted in a relatively small and potentially non-random sample. Therefore, it limits the generalizability of the total educational institutions in the country. The respondents self-reported the survey, and biased information can be reflected. Focusing solely on titration activities provides a snapshot of only one analytical chemistry laboratory work. Furthermore, the study establishes associations but not causal relationships between variables, and the statistical analysis had a specific scope. Finally, the context-specific nature of the accreditation levels and the temporal aspect of the data collection should be considered when interpreting the results.

3.2. Practical implications for education policy or development of alternative tools.

The results of the study imply that the accreditation level of the institutions affects the conduct of neutralization and complexometric titration activities, indicating that the level of accreditation may have influenced the frequency of performing the activities. The availability of titration equipment was not associated with the level of accreditation, indicating the presence of some of the equipment that was not utilized due to the unavailability of reagents. The availability of reagents for neutralization and complexometric titration significantly differed among the institutions with different accreditation levels. The burette-to-student ratio varied across the institutions with different accreditation levels, ranging from 1 to 40 students per acid burette and 1 to 13 students per base burette. The institutions with higher accreditation tend to have lower student-to-burette ratios, suggesting that group work and hands-on learning are conducive. Compared to lower accredited institutions, they have more significant ratios and lack burettes, which might affect the quality of experiential learning. The variations in student-to-burette ratios affect the implementation of the BSEd major in science curriculum, specifically the teaching and learning experiences in Analytical Chemistry.

The study suggests that lower-accredited institutions face significant resource constraints. Education policies should prioritize the equitable distribution of laboratory equipment and reagents. Dedicated funding mechanisms must be established for funding laboratory infrastructure and supplies in lower-accredited institutions. Resource sharing initiatives must be encouraged between higher and lower-accredited institutions within the province. The accreditation standards and resource requirements in educational institutions must be complied with by having the essential equipment, like burettes. There must be regular quality assurance audits to ensure the sustained compliance of the educational institutions. The reported lack of teacher experience and training in conducting certain titration activities highlights the need for professional development programs. Provision of hands-on training for analytical chemistry instructors on the least performed titration activities must be provided.

The lack of laboratory assistance was identified as a barrier. Policies should be considered to reduce the teacher workload and enhance laboratory safety. Lastly, the large class size can be addressed by providing flexible grouping strategies and alternative quantitative analysis methods. Given the resource-constrained lower-accredited institutions, the development of low-cost or improvised titration equipment and virtual simulations can supplement titration education.

4. CONCLUSION

Based on the results gathered and analyzed, the accreditation level was strongly associated (Cramer's V = 0.845 and 0.839) with the conduct of strong acid and base titration, strong base and weak acid titration, and complexometric titration. The activities that were least performed were REDOX, complexometric, and precipitation titrations. There was no association between the availability of titration equipment and accreditation level. However, a moderate association (Cramer's V = 0.500) was found between the availability of titration reagents for complexometric titration and accreditation level. Therefore, the conduct of complexometric titration was not possible even when the equipment was available. The student-to-burette ratios provided a picture of how the titration activities were conducted. The ratios of 1:13 to 1:40 conclude the demonstration method conducted by analytical chemistry instructors. The analytical chemistry instructors reasoned that the unavailability or lack of titration equipment and reagents, class size, lack of training and experience, and lack of laboratory assistance for the non-performance of the titration activities. The advantage of having additional funds among institutions with higher accreditation levels might have provided the needed titration equipment and reagents. Therefore, educational institutions must aim for higher accreditation levels to compensate for the unavailability of titration resources and produce high-quality science teachers.

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