STUDENTS' PERFORMANCE UNDERSTANDING IN VOLUMETRIC ANALYSIS - STEP-TO-STEP MEASUREMENT OF LABORATORY SKILLS

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Abstract

A research study was designed to investigate students' performance understanding in volumetric analysis by measuring step-to- step skills of the experimental technique. The investigation was carried out upon 360 male students of grade 12 from public sector colleges of Lahore. The significant difference among the colleges was also identified. The investigation categorized students' performance understanding of various skills into three levels, strong, moderate and weak.

Introduction

Practical work was at first the part of university education; however, later on its significance could be acknowledged for secondary education (Waldrip, 1994). Kirschner and Meester (1988) view the purpose of lab work to exhibit basic laboratory techniques, to set up laboratory equipment correctly, to know and apply some generally useful measuring techniques for improving reliability and precision, to carry out accurate measurements, and to observe substances phenomena both qualitatively and quantitatively. In the lab, the students work with instrumentation, glassware and other by which the chemistry laboratory goals are associated with psychomotor domain (Fay 2008, & Hussain 1998). There are seven levels of psychomotor domain from lowest to highest: perception, set, guided response, mechanism, complex overt response, adaptation and organization. At ‘organization’, the highest level, the proficiency level is very high, the performance is smooth and spontaneous (Rehman 2004; Linn & Gronlund, 2005, p. 572). Students at school and college level are expected to repeat an act as demonstrated by instructor, and it is imitation as viewed by Simpson (1972, as cited in Linn & Gronlund, 2005, p. 572). Imitation is a characteristic of third level ‘guided response’ of psychomotor domain where the students’ control and confidence on his or her performance is low, however, they are taught that how to minimize human errors. Hussain (1998) views that the science lab introduce students to the importance of measurement and accurate collection of data, therefore, they learn how to establish control. Reif and John (1979, as cited in Lippman, 2003) argue that students must be capable to use general measuring techniques to improve reliability and precision. Buckley and Kempa (1971, as cited in Fay, 2008) hold their trust on the aim of practical work as to encourage accurate observations and careful recordings. According to Linn and Gronlund (2005, p. 73), learning is conceptualized as being hierarchical, with higher-order skills dependent on a linear development based on a foundation of lower-level, that is, essential skills. Beasley (1978) emphasizes upon learning motor skills that the magnitude of practice and subsequent learning is a function of the period of time and the number of repetitions by an individual. In other words, there may be a risk for an individual to be accustomed for doing small mistakes instinctively if s/he does not increase her/his magnitude of practice on a particular skill. But human error in science does not make sure the guarantee of true measurements and resultantly the results can not be obtained reliable. Beasley (1978) has reported the results of a study on laboratory psychomotor skill development and related with students' learning improvements. He concluded that the degree of improvement is proportional to the investment of students' time and laboratory resources in the practice activities.

Research questions

This research study deals with the following research questions:

a. What is the performance understanding of students of grade 12 in volumetric analysis?
b. Is there any significant difference among students of different colleges related to their performance understanding in volumetric analysis?

Method

The target population was students of grade 12 doing their F.Sc with chemistry. The sample was consisted of 360 students from all 12 public sector male colleges of Lahore. Thirty students were selected at random from each college and divided into two groups each with the strength of 15 by random assignment.

A comprehensive image of lab skills related to volumetric analysis was sketched out after spending time in lab for taking observations of the students doing experimental work. Step-t-step skills were categorized into the use of pipette, use of burette, taking end point, calculations, and making solution dilute with the score split up as shown in Table 1. The observational checklist was named 'chemistry laboratory skills investigation tool (CLSIT)'.

Table 1

Summary of Chemistry Laboratory Skills Investigation Tool (*CLSIT*)

Experimental Technique	Score Range	Experimental Skills	Score Split Up	Data Collection Tools
Volumetric Analysis	0 – 32	Use of Pipette	6	Observation
		Use of Burette	8	Observation
		Taking End Point	6	Observation
		Calculations	8	Paper-Pencil Test
		Making Solution Dilute	4	Observation

A team of three researchers practiced on the observational checklist for two sessions 15 + 15 students and made it possible to minimize the time consumed and to be more effective. Each observer had to observe five students in a group of fifteen.

The coefficient alpha reliability of CLSIT was obtained 0.64 on the implementation upon the sample size of 360 students.

Results

The descriptive information revealed that the groups were homogeneous except C9, which exhibited high value of standard deviation, as shown in Table 2. The overall performance of students remained excellent in volumetric analysis with high mean values and even the lowest mean score, 20.60, was not much below to the combined average of all means.

Table 2

Between Groups Comparison on Descriptive Statistics

Sr. No. of Colleges	Mean ± SD	Score Range
C1	22.27 ± 3.04	15 – 26
C2	25.07 ± 2.45	18 – 29
C3	22.67 ± 2.77	14 – 26
C4	22.73 ± 2.29	16 – 26
C5	22.63 ± 2.08	19 – 26
C6	24.00 ± 3.30	14 – 28
C7	22.77 ± 2.21	16 – 26
C8	22.03 ± 3.68	14 – 28
C9	20.60 ± 6.37	8 – 28
C10	25.33 ± 3.84	10 – 29
C11	24.17 ± 2.87	14 – 27
C12	21.47 ± 2.57	14 – 25
Combined Average of All Means	22.98 ± 3.53	8 – 29

The one-way ANOVA was significant, F (11, 348) = 5.47, p < .001. revealed significant differences between groups on their students' performance understanding in skills related to volumetric analysis.

Students' performance understanding was measured by comparing the means of items. Highest score on an item was 2.00. The skills were manipulated into three levels, weak, moderate and strong with the break up of item score as under:

Levels of Skills	Break Up of Item Score
1. Weak	0 – 0.90
2. Moderate	0.91 – 1.09
3. Strong	1.10 – 2.00

The means of items are reported in Table 3. It was observed that there was no practice of using pipette filler. Students sucked the solution by mouth. They were good in adjusting lower meniscus of a colorless solution in pipette and to discharge its liquid into titration flask. However, wastage of liquid as well as blowing air through pipette (to flow out the little liquid stay at tip) were observed. Students were skillful in some aspects of using a burette, as reported in Table 3, even though, some mistakes and mishandlings were observed, such as, solution was poured into burette without funnel. It was also noticed that there was a general practice of releasing burette solution into titration flask with fast flow instead of drop wise.

Majority of students calculated the molarity by using correct formula except for one college. It was also estimated that students of many colleges were weak in determining volume of less dilute solution required for making more dilute solution, however they could write correct formula for this problem.

For making a solution, the best and caring choice is to use round / flat bottom flask with mark on neck for adjustment of solution volume. Almost students of all the colleges could not use proper apparatus; instead they used beaker or measuring cylinder. For that reason, the adjustment of lower meniscus was also improper and false.

Table 3

Between Groups Comparison Summary on Levels of Skills

Experimental Skills	Skills Investigated	Level of Skills Identified			MPI*	MPI* Experimental Skills
		Weak	Moderate	Strong		
Use of Pipette	va1	12 Colleges	Nil	Nil	.03	1.31
	va2	Nil	Nil	12 Colleges	1.96	
	va3	Nil	Nil	12 Colleges	1.93	
Use of Burette	va4	Nil	Nil	12 Colleges	1.94	1.86
	va5	C12	C9	10 Colleges	1.52	
	va6	Nil	Nil	12 Colleges	2.00	
	va7	Nil	Nil	12 Colleges	2.00	
Taking End Point	va8	12 Colleges	Nil	Nil	.44	1.25
	va9	Nil	Nil	12 Colleges	1.89	
	va10	Nil	C5	11 Colleges	1.42	
Conclusions	va11	Nil	Nil	12 Colleges	1.78	1.56
	va12	C8	Nil	11 Colleges	1.63	
	va13	Nil	Nil	12 Colleges	1.66	
	va14	C3, C4, C5, C7, C12	Nil	7 Colleges	1.17	
Making Solution	va15	12 Colleges	Nil	Nil	.05	.81
Dilute	va16	8 Colleges	Nil	C2, C9, C10, C12	1.57	

* MPI (mean per item)

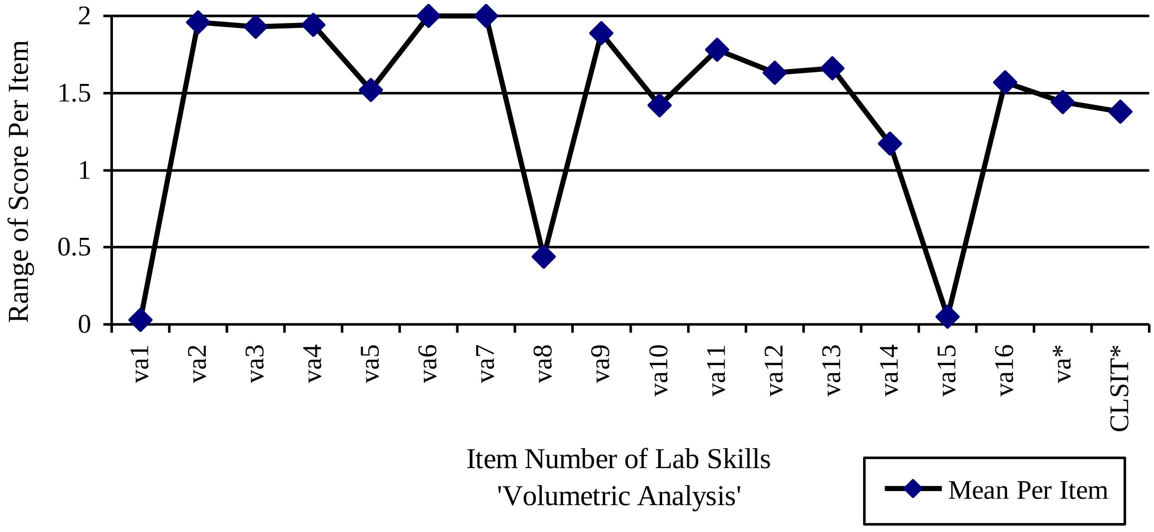

Figure 1: Students' score on different laboratory skills related to volumetric analysis

Discussion

Carr and Kemmis (1978, p. 28) argue that education is a human encounter whose aim is the development of unique potentials among individuals. Science can not be meaningful to students without worthwhile practical experiences in the laboratory (Hofstein 2004). Volumetric analysis (titration) is a quantitative technique of measurement. This technique is used to standardize a solution with the help of a standardized solution. For example, an acid solution of unknown molarity can be standardized by titrating it with a base of known molarity. This is the first and most essential step of titration. Many other calculations are involved but all depends upon the calculation performed for knowing an unknown molarity. For example to find out the percentage composition of a mixture of solution, to find out percentage purity and impurity of a substance, to find out solubility of a substance, making a more dilute solution from a less dilute solution, and even atomic and molecular masses can also be determined. Thus, having a prime importance the titration technique is widely used in chemistry laboratory. This technique is taught at high and higher secondary levels and as being its nature of quantitative measurement all the experimental steps are sensitive which demand careful handling. A small mistake can perform all the further calculations wrong. Thus, this research work was designed to investigate the very initial and basic steps' accuracy in performance by the students. The use of pipette and burette, taking end point, calculations and making dilute solution were the experimental skills identified.

Students of all colleges were good in use of pipette and burette with some mistakes. It was observed that the pipette fillers were not used and students were habitual for sucking through mouth. This was not the safe way and observed many mishandling by which solution entered into the mouth of students. Furthermore, with the help of thumb the adjustment of meniscus was a problem which could easily be performed with pipette filler. It was noticed that such malpractice was playing and came to know that many laboratories did not have pipette fillers or if had then not in working condition.

Titration depends upon accurate calculations of volumes of solutions. A chemical reaction takes place between two solutions: one in titration flask and the other in burette when it is dropped in flask. A color change indicates the end point. An indicator is used in acid-base titration. The end point variation takes place just with the difference of one or two drops. Thus, a more careful observation and handling is required. Nevertheless, it was observed that students were not caring for falling burette solution into titration flask. They had a practice to flow the solution more or less first up to 7 – 8 cm^3 with fast discharge then drop wise. It was for the reason that the volume of burette solution consumed is adjusted at 10 cm^3 for F.Sc. level and every student is familiar with this fixed reading. On the other hand, Adey and Shayer (1994, p 18) argue that for higher order thinking all experiments involve the notion of controlling variables and students change more than one variable, and then attribute any effect to both variables.

Students were good in molarity calculations but did not perform well in volume calculation. These were simplest calculations, even then students of majority of colleges solved incorrect for the most part ‘the volume of less dilute solution required’. Students could not control the identify the relationship between variables involved in calculation. It was the simple relationship as:

$$M_1V_1 = M_2V_2$$

M_1 the molarity of less dilute solution, V_1 the volume of less dilute solution required for more dilution; M_2 the molarity of more dilute solution, V_2 the volume of more dilute solution required to prepare. However, students could not solve the problem by developing such a simple relationship. Whereas, Adey and Shayer (1994, p 18) suggest that ratio and proportion, compensation and equilibrium, correlation, probability are the important components which are required to understand the relationship between variables. It was also noticed that mostly students used incorrect units of molarity and volume.

Chemistry laboratory work depends upon the preparation of solutions which is the most essential skill. Students were asked to make a more dilute solution from less dilute solution of NaOH. They were asked to take 10 cm^3 volume from less dilute and prepare its 100 cm^3 solution in water. It was noticed that the students of all the colleges used beaker of 100 cm^3 or measuring cylinder instead of round / flat bottom flask with long neck marked for accurate volume adjustment. That was the cause for inaccurate measurement of lower meniscus. The major cause behind this neglectful practice might be that at F.Sc. level the solution preparation activity had not given to students but they just got prepared ones from lab staff. Hofstein (2004) argues that students interact with materials in labs. If they are not familiar with the lab materials then their right choice for conducting a particular experimental step would be untrustworthy.

Laboratory activities are essential for learning basic laboratory skills such as using a thermometer, measuring out a certain volume of liquid or developing observational skills (Hussain 1998). There are many examples where students may perform with inaccuracy such as mishandling of apparatus, inaccurate determination of end point of titration, unfamiliar with or confusing the color or odor identification of fumes. These mistakes may be due to the reason of lack of practice or inefficient teaching-learning process. These are the teaching strategies that come to know the performance of students in lab by means of formative assessment and to do diagnostic measures. Gillespie (2004, as cited in Burger 2008) views that formative assessment is a continuous planned process of gathering information on learner's performance. The laboratory curriculum should be designed as viewed by Carr and Kemmis (1978, p. 28) to provide information and skills and to create, maintain, monitor, and assess students' progress in learning.

Educational Implications

1. There is a need to highlight the importance of accuracy and precision of scientific investigation among the students. It is also required to enhance students' skills to the higher order of psychomotor domain, so that to avoid inaccuracy in analysis and to develop proficiency in motor act. A lot of practice that should also be guided with formative assessment is necessary. Teachers should be trained and skillful how to use this assessment technique in an effective way.
2. Chemistry is a field of prime importance for the nation. There is a need to make the students familiar with the practical application of the subject. They take the experimental work just a part of syllabus as a need of F.Sc certification. By this way, the lab work is more to be an exam-driven activity rather than a mean of learning skills and enhancing cognitive development. Furthermore, to make experimental work more interesting the life-related curriculum should be designed. Holbrook (2005) argue that the lack of relevancy of chemistry teaching with practical life has created many problems such as this subject is irrelevant and

unpopular among students, do not promote higher order thinking, there is a gap between teachings and students' interest, and teachers are not willing for change. Holbrook suggests a change in the meaning of chemistry education from 'chemistry through education' to 'education through chemistry' to solve such problems.

3. Lab staff is also helping for the teachers and have a vital role for the effectiveness of lab work. Mostly, they supervise students' discipline, properly working of groups and also guide them on some sort of problems especially handling apparatus. Government should create new posts of lecturer coordinators with minimum qualification of graduation in chemistry and their pre-service and in-service training should be conducted by Directorate of Staff Development (DSD).

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Appendix

Step-to-step skills of volumetric analysis

va1. use of pipette filler

va2. taking desired volume by reading lower meniscus

va3. discharge of liquid into titration flask without splashing or blowing air

va4. adjusting in stand properly

va5. filling the solution with funnel

va6. adjusting initial reading

va7. filling with acid instead of alkali

va8. falling solution into titration flask drop- wise

va9. constant whirling

va10. end point noting just to colorless

va11. use of correct formula for molarity calculation

va12. putting correct values & calculating unknown molarity

va13. use of correct formula for making dilute solution

va14. putting correct values & calculating volume of less dilute solution required

va15. taking flask of 100 c.c.

va16. making volume up to mark with adjusting lower meniscus of colorless solution