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Relationship between inquiry-based learning and students' attitudes towards chemistry

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ABSTRACT

Students' attitudes towards science subjects and especially chemistry have been attributed to the use of inquiry-based learning (IBL). The students' attitudes are important predictors of academic achievement. The consistently poor performance in chemistry among secondary school students has been an issue of concern. This study sought to establish whether IBL has been used in the teaching of chemistry and if it had any influence on students' attitudes towards chemistry. The study employed a correlational research design that involved conducting a survey of 21 teachers who were purposively selected, and 357 students selected through simple random sampling from the 21 classrooms that these teachers taught. The results revealed that teachers used IBL once a week (M=4.062) and students had positive attitudes towards chemistry (M=3.945). Besides, there was a significant association between IBL and the attitudes of students towards chemistry ($r=0.997$, $p<0.05$, $R^2=0.994$).

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1. INTRODUCTION

Attitude of students in chemistry is a factor that researchers have been interested in and theorists and practitioners have agreed on the significance of such attitudes in predicting students learning outcomes [1], [2]. Positive or negative feelings toward chemistry are referred to as attitudes [3]. Attitudes have three components which include cognitive, affective, and behavioral [4]. The cognitive component stems from previous chemistry instruction and impacts students' confidence. The affective component deals with a person's subjective emotional reactions to an item, while the conative component is the proclivity to act or behave in specific ways in the presence of objects.

Improvement of attitudes of students in chemistry is important because it is closely linked to academic achievement and it predicts behaviors [1]. Besides, attitudes are important factors that affect students' learning and achievement [5]. Since attitudes influence academic achievement, students with positive attitudes are likely to perform better in chemistry [6]. However, even though attitudes predict performance, dismal performance in chemistry in Meru South Sub-County has been witnessed [7].

Students' positive attitudes may be improved by employing engaging educational approaches such as inquiry-based learning (IBL) [5]. Instructional practices are a significant element influencing student learning outcomes and assessing the effects of various types of instructional practices on critical outcomes such as attitudes and academic accomplishment is essential [5]. As a result, it is necessary to investigate changes in students' attitudes and learning experiences to ensure academic excellence in chemistry teaching and learning [8].

In inquiry-based learning, students actively participate in the learning process by posing and answering questions, evaluating evidence and assessing and proposing answers [9]. The strategy employs an inductive method to knowledge discovery while focusing on student action. Inquiry learning allows students to develop knowledge and learn via active engagement with concepts and principles [10].

Inquiry-based learning has been associated with positive attitudes towards science [11]–[13]. It has been positively linked with positive views toward sciences in a meta-analysis [11]. Also, inquiry teaching has been associated with increased attitude scores [14]. Besides, guided inquiry has significant positive effects on students' attitudes in chemistry [12]. Furthermore, using a stepwise inquiry technique can improve students' attitudes [13]. In a longitudinal study of the effects of an inquiry program on the attitudes of students, the results revealed that students maintained positive attitudes towards science [15]. Inquiry-based strategies which involve hands-on activities are more effective compared to traditional methods of instruction such as lectures [15]. However, there is a modest body of evidence that supports the premise that inquiry-based instruction fosters positive attitudes among students in chemistry, as new research analyzes the effects of inquiry-based instruction on secondary school student attitudes toward science [5].

The engage, explore, explain, elaborate, and evaluate or 5E model is one of the frameworks used to integrate inquiry-based learning in scientific classes [16]. The 5E learning model ensures that students are engaged in class, that they have the opportunity to investigate and analyze, and that they gain knowledge by facilitating conversation and asking questions. Engagement, exploration, explanation, elaboration, and evaluation are the five steps that make up the model [17], [18]. Instructors make use of the activities in each phase to ensure learners are actively engaged.

In scientific education, inquiry has traditionally been defined as student-centered interactions, student explorations, and hands-on activities, with a focus on science models or applications [19]. These are the core activities for laboratory work and therefore, practical lessons provide the best opportunities for IBL. Laboratories are used not only to increase psychomotor skills but also to promote problem-solving abilities, and to assist students to build positive attitudes [13]. Inquiry-based laboratories promote meaningful learning, conceptual knowledge, interest, motivation and understanding of science's nature [20].

In Kenya, laboratories are always set aside for experiments with theoretical lessons being taught in normal classes. The practice entails combining two lessons to create a lab space. This approach has created a notion of theory and practical lessons. The national assessment extends this notion by giving three papers: one testing shallow but wide understanding, the other testing narrow but deep understanding, and the other practical. The practical part is very important for the students' success in chemistry. This study sought to find out whether there is any relationship between the use of IBL approach in chemistry practical lessons and the students' attitudes towards chemistry.

2. RESEARCH METHOD

This study adopted a correlational research design and quantitative method. This design allows the establishment of the relationship between quantitative variables that have not been manipulated [21]. Quantitative data was collected through teachers' and students' surveys.

The participants were: 21 form three chemistry teachers (17 males and 4 females) and 357 form three chemistry students (159 males and 198 females) from 21 secondary schools in Meru South Sub-County, Tharaka Nithi County, Kenya. The teachers who took part were chosen using purposeful sampling, whereas the students were chosen using simple random sampling. Yamane formula was used to identify the number of students from a total of 3,321 form three students [22] as shown in (1).

$$n = \frac{N}{1+N(e)^2} \quad (1)$$

Hence, $n = \frac{3,321}{1+3,321(0.05)^2} = 357$

Where,
n=sample size
N=total population
e=precision level

The formula was selected for this study because the population for the study was known and hence the sample size could be accurately obtained. There were 17 students selected from each school to participate in the study. Respondents were assured of the confidentiality of their information and consent was sought from them to take part in the research.

Teachers' questionnaire and students' questionnaire were the two instruments used in this study. Teachers' questionnaire was used to determine IBL use in chemistry practical lessons. The questionnaire had 10 items where each phase of the 5E model was represented by two items. The items were scored on a 5-point Likert scale, where 5=every lesson, 4=once a week, 3=once a month, 2=once a term, and 1=never. The items were selected based on the existing literature [17], [23], [24]. The authors agreed on the items to be included and the results from the interrater reliability were 0.937 implying that there was a strong agreement between them [25]. Three specialists from the University of Embu, school of education and social sciences assessed the questionnaires' face and content validity. Before the actual study, a pilot study was conducted where two form three chemistry teachers outside the study area were asked to fill out the questionnaire. The reliability of the items was found to be good (α=0.802).

The students' questionnaire had 15 items based on a 5-point Likert scale (5=strongly agree, 4=agree, 3=not sure, 2=disagree and 1=strongly disagree). The items were adapted from existing literature [6], [26]. The items were cross-checked by three experts to ensure face and content validity. In addition, the interrater reliability between two authors was 0.913 and therefore, there was good agreement on the items selected to measure students' attitudes towards chemistry. The items were piloted with a total of 90 Form three students outside the study area. Data was subjected to exploratory factor analysis (EFA) and principal component analysis (PCA) resulting in two attitude sub-scales with Cronbach alpha of 0.791 and 0.770. Thereafter, the questionnaire was administered to 357 students and the resulting data was also subjected to EFA and PCA. The results led to the removal of one item which had a low factor loading. The final scale had a Cronbach reliability of 0.862, with two subscales, that is, "affect for chemistry and practical lessons" and "value and beliefs about chemistry" with reliabilities of 0.785 and 0.783 respectively.

2.1. Data analysis

Data analysis was carried out with the help of the R software and SPSS where means, frequencies, percentages, correlation test, and regression analysis were computed. Regarding IBL use, frequencies and percentages were determined for each response category, that is, for every lesson (EL), once a week (OW), once a month (OM), once a term (OT), and never (N). The mean for each phase of the 5E model was determined, which was arrived at by computing the average of the five response categories in each phase. Every lesson had 5 points, once a week 4 points, once a month 3 points, once a term 2 points, and never 1 point. A mean of 4.5 and above was categorized as every lesson, mean of 3.5 to 4.4 was classified as once a week, 2.5 to 3.4 was classified as once a month, 1.5 to 2.4 was classified as once a term, and 1.4 and below was classified as never. For the students' attitudes, the mean for each item was determined by computing the average of the five response categories for the item which include: strongly agree (SA), agree (A), not sure (NS), disagree (D) and strongly disagree (SD).

3. RESULTS AND DISCUSSION

The results of teachers' ratings on IBL use are presented in Table 1. According to the table, the means for the five phases were engagement (M=4.76), exploration (M=3.57), explanation (M=4.265), elaboration (M=3.215) and evaluation (M=4.50). The results revealed that teachers made use of the engagement activities in every practical lesson (M=4.76). This is evident from the percentages where 81% of the teachers said that they engage learners in every lesson. Based on the results, it was deduced that teachers allowed learners to design and carry out experiments once a week (M=3.57).

In regard to this, the larger percentage of the teachers (52.4%) said that they allowed learners to carry out exploration activities once a week. From the results, it is evident that teachers provided detailed explanations for investigations to be undertaken by students once a week (M=4.265). On the other hand, the results revealed that teachers provided learners with opportunities to extend their knowledge into new situations once a month (M=3.215). Lastly, teachers assessed learners' understanding in every practical lesson (M=4.50), where 61.9% of the teachers' evaluated concepts studied in every practical lesson. The total mean for the five phases was 4.062, implying that teachers practiced IBL in practical lessons once a week.

The status of students' attitudes towards chemistry was determined. The results are presented in Table 2. The overall item mean was 3.945, approximately 4.0. The item means ranged between 3.42 and 4.38. A mean above 3.0 indicates a positive attitude towards a subject while a mean below 3.0 indicates negative attitude [27]. This clearly shows that the students exhibited a positive attitude towards chemistry.

Table 1. Teachers' ratings on IBL use

	EL	OW	OM	OT	N	Mean	SD
Engagement	17 (81%)	2 (9.5%)	2 (9.5%)	0 (0%)	0 (0%)	4.76	0.578
Exploration	4 (19%)	11 (52.4%)	2 (9.5%)	1 (4.8%)	3 (14.3%)	3.57	1.286
Explanation	13 (61.9%)	5 (23.8%)	1 (4.8%)	1 (4.8%)	1 (4.8%)	4.265	1.144
Elaboration	6 (28.6%)	3 (14.3%)	4 (19%)	5 (23.8%)	3 (14.3%)	3.215	1.473
Evaluation	13 (61.9%)	6 (28.6%)	1 (4.8%)	1 (4.8%)	0 (0%)	4.50	0.779
Total mean						4.062	1.052

EL=every lesson, OW=once a week, OM=once a month, OT=once a term, N=never

Table 2. Students' attitudes towards chemistry

No	Items	Mean	Std. Dev
1.	I know that I will require chemistry knowledge in my future career	4.28	0.880
2.	When I do practicals, I can come up with answers to challenging tasks on chemistry	3.86	0.972
3.	Chemistry is a crucial subject that people need to study	4.06	1.118
4.	I like attempting challenging tasks in chemistry	4.01	0.941
5.	I feel empowered when I am doing experiments in the laboratory	4.38	0.824
6.	Chemistry is important for providing solutions to daily life problems	3.59	1.122
7.	I intend to take a career related to chemistry to get a good job in future	3.82	1.348
8.	We have interesting exercises in chemistry	3.88	1.075
9.	I will be happy to dedicate most of my time to doing experiments	4.19	1.035
10.	People need to get an understanding of chemistry since it influences their lives	3.58	1.172
11.	I like to do chemistry experiments	4.00	1.060
12.	I enjoy chemistry lessons	4.34	0.827
13.	Given an opportunity, I can carry out a project in chemistry	3.82	1.234
14.	Chemistry is an easy subject	3.42	1.297
	Overall item means	3.945	1.065

To find out the link between IBL and students' attitudes towards chemistry, students' attitude scores were matched with their teachers' practice of IBL, and correlation and regression analysis were computed. The correlational results are presented in Table 3. The results revealed a strong positive correlation between IBL and students' attitudes towards chemistry (r=0.991, p=0.000) at 99% confidence interval.

Table 3. Pearson's correlation between IBL and attitude of students

		Inquiry-based learning
Attitudes	Pearson correlation	0.997
	Sig. (2-tailed)	0.000
	N	21

**Relationship is significant at 0.01 level (2-tailed)

To compute regression analysis, the statistical assumptions of linearity, independence, homoscedasticity, and normality were checked. The assumptions were all met as illustrated in Table 4 (Durbin Watson test), and Figures 1 to Figure 3. The results from regression analysis are shown in Table 4 and Table 5. Figure 1 shows that the linearity assumption for regression analysis was met, Figure 2 shows that the homoscedasticity principle was not violated, while Figure 3 shows that the normality test was met.

Table 4. Model fitness

Model	R	R square	Adjusted R square	Std. Error of the estimate	Durbin-Watson
1	0.9972	0.994	0.994	0.02292	1.908

Table 5. Analysis of variance; IBL vs attitudes

	Model	Sum of squares	df	Mean square	F	Sig.
1	Regression	1.785	1	1.785	3,397.116	0.000
	Residual	0.010	19	0.001		
	Total	1.795	20			

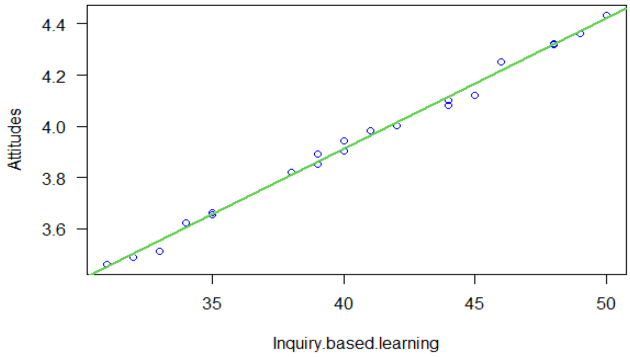

Figure 1. A plot of attitudes vs inquiry-based learning

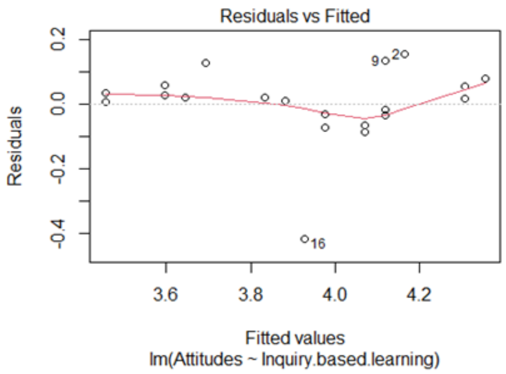

Figure 2. Residuals vs fitted values; attitudes and IBL

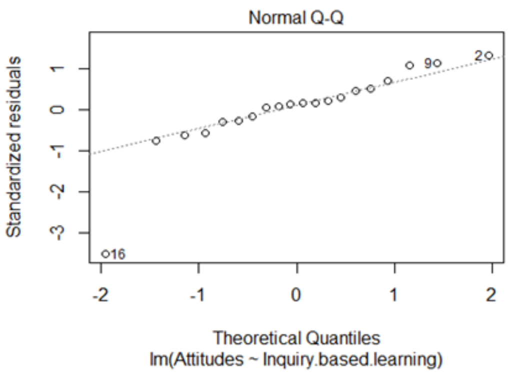

Figure 3. Q-Q plot for attitudes

Results from regression analysis revealed that up to 99% of the students' attitudes could be attributed to the use of inquiry-based learning while teaching, R^2=0.994, F (1, 19)=3397.116, P=0.000. Also, there is a strong relationship between IBL and students' attitudes towards chemistry, t=58.285 p<0.05, VIF=1.000. This study examined IBL use in practical lessons, students' attitudes towards chemistry and the relationship between the two variables. According to the study results, IBL was used once a week based on the descriptive statistics (M=4.062). A similar study also found that teachers practiced IBL more while teaching chemistry as compared to biology and physics lessons [28]. From this study, it is evident that students had minimal opportunities to explore and extend their learned knowledge to new situations. These results are consistent with the findings of a study where teachers rarely allowed learners to design experiments as well as providing opportunities for students to enhance their understanding [23].

Students' attitudes towards chemistry were found to be positive (M=3.945). The mean was approximately 4.0, implying that most of the students agreed with the positive items about chemistry. Similar findings were obtained where non-native finish speakers had more positive attitudes towards chemistry compared to native finish speakers despite challenges that could be attributed to language and culture [6]. Also, another study found that students developed positive attitudes towards chemistry as a result of active engagement through group work [8]. In addition, student teachers had positive attitudes towards the learning of chemistry [29].

There was a positive association between IBL use and students' attitudes towards chemistry based on the correlation and regression analysis. The results are in agreement with the findings from several studies [4], [11]–[15], [30]–[32]. In a quasi-experimental research, students in the experimental group were found to have more positive attitudes when compared to students in the control group [30]. The guided inquiry learning approach is an effective strategy for instilling positive attitudes among students [30]. This is supported by the fact that guided inquiry can improve students' scientific attitudes [31]. Results from a study done in Indonesia on the application of guided inquiry to enhance attitudes of students towards physics concepts found that, students exposed to the guided inquiry had improved attitudes compared to the control group [31]. Besides, it was discovered that training that focuses on inquiry-based laboratory activities results in significantly higher favorable views toward chemistry and laboratory activities [32].

Inquiry-based laboratory activities should therefore, be developed and applied to improve students' attitudes [32]. Furthermore, results from a meta-analysis revealed that inquiry-based learning has a favorable impact on students' attitudes toward science [11]. This implies that the more a teacher employs the inquiry approach in teaching, the more students develop interests in chemistry. This means that teachers in chemistry education need to shift their teaching methodologies from teacher-centered to learner-centric methodologies. Learner-centered methodologies ensure active learner engagement which translates to better understanding and hence effective learning.

4. CONCLUSION

Based on the outcomes of the study, there is a strong positive relationship between the utilization of inquiry-based learning approach in chemistry practical lessons and students' attitudes towards chemistry. This means the more a teacher practices IBL, the more students improve their attitudes towards chemistry. Teachers should therefore be encouraged to maximize the use of IBL in the teaching of chemistry because of its association with attitudes of students towards the subject. This can aid in instilling positivity towards chemistry among students, which will translate to improved performance in chemistry. Future research should investigate the correlation between specific levels of inquiry-based learning and learning outcomes.

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