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CLASSROOM: TEACHING CHROMATOGRAPHY IN JUNIOR SECONDARY SCHOOLS USING LOCAL MATERIALS

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ABSTRACT

Local or inexpensive materials were used to develop models for teaching chromatography. The models were tried in two Junior Secondary Schools to find out if they could enhance the understanding of the topics. The results showed that using chalk stick, yam and cassava chips as stationary phase and water as mobile phase in separating the components of BIC black ink, yellow colour moved out first followed by red (deep pink) then blue - black colour for chalk stick, whilst for cassava and yam chips the ink separated with red colour first followed by blue-black colour and the separation was very slow. When locally manufactured alcohol (akpeteshie) was used in place of water, black ink from BIC pen separated with more distinct colour bands and the separation was very fast and the colour bands were very distinct. When syringe was used as the column, black ink from BIC pen as the mixture, water or alcohol as the mobile phase and chalk powder, maize powder or starch powder as stationary phase in the syringe, chalk powder as stationary phase and alcohol as mobile phase produced the best result where more colour separation took place. Ink with trademark name KOFA produced very poor colour separation when used in both cases. The trial results showed that the models enhanced the understanding of the topic in those classes that they were used compared to those classes that they were not used. In both schools A and B the differences between the means for the control and test experiments ($t = 3.53$, $P < 0.01$ for school A and $t = 3.50$, $P < 0.01$ for school B) were very highly significant.

KEY WORDS: Chromatography, Model, Black ink, Trademark, Colour

INTRODUCTION

One of the most important aspects of chemistry is the analysis of mixtures. Usually a mixture must be separated into pure components before chemical analysis can be attempted (Marov and Stedjee, 1994). Colour provides a vital enhancement to the world in which we live. Everyday materials we use – textiles, paints, plastics, paper, and foodstuffs are especially appealing if they are colourful (Chandrasekaran, 2001). The colour of many things is actually mixed together, but their atoms and molecules are not combined. The different pigments can be separated. The separation of the pigments is achieved by a process called chromatography.

Chromatography is a process of separating mixtures by encouraging different parts of a mixture to move through an absorbing material at different rates (Vancleavis, 1997). According to Kneen, Rogers and Simpson (1972) chromatography enables small amounts of materials present in complex mixtures to be isolated and purified. Holderness and Lambert (1976) considered chromatography as a means of separating the constituents of a mixture by taking advantage of their different rates of movement in a solvent over an adsorbent medium. For each constituent the rate of movement depends on the relative affinities of the adsorbent medium.

The moving phase carries the components through the stationary phase at different rates and separation is achieved. Chromatography is used in industries to separate and measure solutes. It is particularly a valuable technique since it enables us to separate very complex mixtures, even where the components are present in small amounts. (Andrew and Rispoli, 1991).

A number of methods of chromatography can be used depending on the type of mixture involved. One method is called partition or distribution chromatography for which water can be used as the adsorbent whilst silica gel packed in a glass tube (column) serves as the stationary phase. Any material (specimen) applied to the top of the column will move down it at a rate determined by its partition coefficient between the moving phase called eluent and the water adsorbed on to the silica gel, the stationary phase. Another common method used is called thin-layer chromatography. Under this, if a mixture of dyes is applied as a spot on a thin layer of chromatographic adsorbent and placed in a solvent with the spot just above the solvent the moving phase creeps slowly up the plate under the influence of capillarity. According to their partition coefficient, the dyes are carried by the solvent in the form of spots up the plate at different rates. The position reached (solvent front) by the moving phase is marked and the plate dried. The position of various components can be seen as spots if they are coloured or may be rendered visible by a variety of techniques. Thin-layer chromatography is used in separating and identifying the components of mixtures on a very small scale and can also be obtained from the plates if they are required in a pure form for further investigation. A cylindrical glass tank can be used (Kneen *et al*, 1972),

Another method is paper chromatography. It is similar to thin-layer chromatography but uses paper as solid on which water is absorbed. Paper chromatography serves as a separating technique and it can also assist with the identification if the possible compounds in a mixture are available in pure form (Bouma, Udo, and Wiederholt, 1988). We can also have solid-liquid and gas-liquid systems. More than thirty years ago inorganic gases were separated by gas chromatography (Bouma *et al*, 1988). Gas-liquid chromatography is used to separate mixtures of gases and volatile liquids (Andrew and Rispoli, 1991).

Compared with their counterparts of 30 or 40 years ago, modern teachers or trainers have a vast and often bewildering range of instructional materials at their disposal (Ellington and Race, 1985). However, all the methods of chromatography discussed involve materials that need to be imported into Ghana and they are costly to purchase. Being a developing country with numerous economic problems the government of Ghana is not able to buy the materials to cover all the Junior Secondary Schools in the country especially the rural schools. As a result teachers resort to lecturing instead of demonstrating the process of chromatography to the students.

This adversely affects the understanding of the basic principles behind the process of chromatography and makes the students rote learners. According to Martin Jr., Sexton, Wagner and Gerlovich (1994) the learning experiences and opportunities people often recall are those that included active participation. Students learn best when they are actively involved with their learning and where the topics are of interest

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to them. Ellington and Race (1985) observed that teachers need to select suitable materials from those already available, and more importantly to design their own materials to be particularly relevant to individual learning programmes and objectives. Hence, there is the need to find workable substitutes for the materials needed for demonstrating chromatography. Therefore this study was initiated to use local and inexpensive materials to perform simple experiments demonstrating chromatography. The objectives are:

(i) To find out if cassava chips, yam chips and chalk stick used as stationary phase whilst water or locally distilled alcohol (Akpeteshie) can be used to separate the components of black ink; and

(ii) To find out if the components of black ink can be separated by using chalk powder, maize powder or starch powder as stationary phase in syringe column and water or locally manufactured alcohol (Akpeteshie) as mobile phase. To assess to what extent using the set ups can influence students' understanding of the process of chromatography.

METHOD

(i) Use of Chalk Stick, Cassava and Yam chips.

A constriction was made 1 cm from one end of a stick of chalk, cassava chip or yam chip (Plate 1a). Black ink from BIC pen was spilled into a small bottle and a little thinner added to it to make it more fluid. Two drops of the ink were applied to the constricted region of the stick of chalk, cassava chip and yam chip and allowed to dry up. Three small flat basins were each filled with about 3cm^3 of water. The chalk stick, cassava chip and yam chip were placed in the middle of the water in each of the basins making sure that the ink mark was above the water. Later alcohol was used in place of the water. Alternatively, ink with the trademark name KOFA was also used.

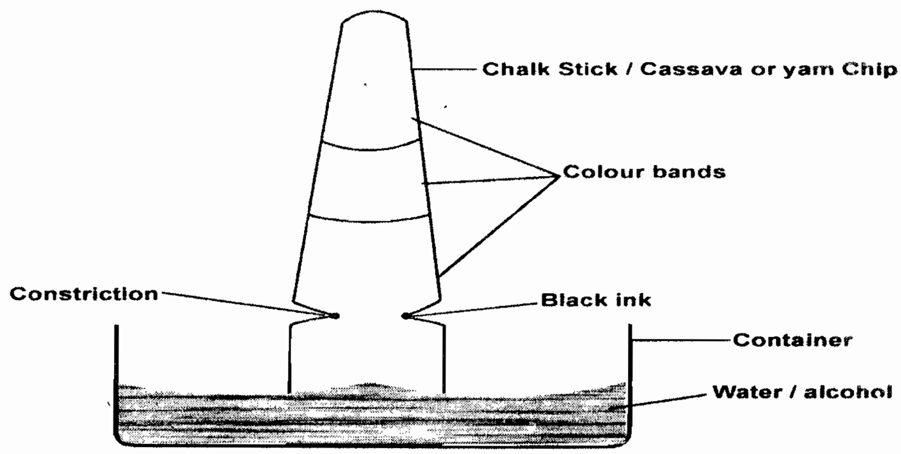

Plate 1a: Chromatography using chalk stick

(ii) Use of Syringe as Column

A piece of cotton wool was put into the constricted region of the barrel of a syringe by using copper wire. Fine sand was put on the cotton wool to the depth of about 3 mm. Chalk powder was then put on the sand 2-3 cm thick. About 4 mm of sand column was then added. Water was added to the column leaving empty space above. Two drops of black ink diluted with thinner were added to the water above the column and the set up left to settle. Observation for colour separation was made .In place of chalk powder, starch powder and maize powder were used and observations made. In place of black ink from BIC pen, black ink with the trademark name KOFA was used. In place of water, alcohol distilled locally from fermented palm wine /sugarcane juice (Called Akpeteshie) was used as the mobile phase (Plate 1 b)

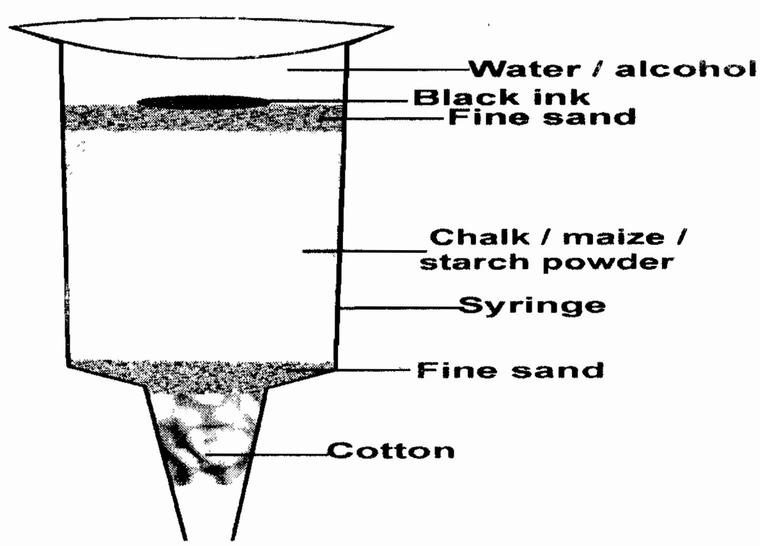

Plate 1b: Chromatography using syringe as column

iii) Trials

The trial involved 200 students from two Junior Secondary Schools (99 from school A and 101 from school B). The models produced were given out to science teachers in the two Junior Secondary Schools to use in teaching the necessary topics. Before the models were used the students in the two schools were assessed with a set of common questions on the topics. This was to find out whatever knowledge they already had about the topics. After marking the pretest scripts those students who scored zero percent (0%) were taken note of and separated from those who scored marks above zero. The students who scored zero in each of the schools were randomly placed in two separate classes. Then students who scored marks above zero were also shared randomly into the two groups. This is to ensure that students with and without prior knowledge of the topic are fairly mixed. In each school one class was taught without using the model (control) whilst the other class was taught using the prepared model (test experiment). The same number of minutes was used in teaching the topics in the two classes. After the lessons, the same questions were administered to the two classes and the scripts marked by the teachers using the same marking scheme and the marks recorded. To be certain that the teachers actually marked the scripts correctly, one fifth (1/5) of the number of scripts in each class was randomly selected by the researchers and crosschecked with the marking scheme. The posttest scores of students who scored marks above zero in the pretest were cancelled. From each class in the two schools, scores of thirty (30) students were selected randomly from the remaining students for analysis. This was done by giving numbers to each student such as 1, 2, 3, 4, 5.. to cover the number of students in each class. Each number was written on a piece of paper and folded. All the folded pieces of paper bearing the numbers were placed in a plastic bowl, mixed up and thirty selected without replacement with intermittent mixing. The pieces of paper were then opened up and the corresponding mark recorded (Hordzi and Mensah, 2003).

ANALYSIS OF RESULTS

The frequency of marks and their percentage frequencies within certain range in relation to the Ministry of Education grading system for Junior Secondary schools were calculated. Thus:

Grade $A^+ \rightarrow 90 - 100\%$ = Distinction
Grade $A \rightarrow 80 - 89\%$ = Excellent.
Grade $B^+ \rightarrow 70 - 79\%$ = Very Good.
Grade $B \rightarrow 60 - 69\%$ = Good.
Grade $C^+ \rightarrow 55 - 59\%$ = Credit.
Grade $C \rightarrow 50 - 54\%$ = Satisfactory.
Grade $D \rightarrow 40 - 49\%$ = Weak.
Grade $E \rightarrow 35 - 39\%$ = Very Weak.
Grade $F \rightarrow 0 - 34\%$ = Fail

Percentage frequencies obtained were used to draw graphs. The mean percentage marks obtained by students were also calculated. The differences between the means of the control and test experiments of each school; between the means of control experiments and between the means of the test experiments of the two schools were compared by using independent t-test

RFSULTS AND DISCUSSION

(i) Use of chalk stick, cassava and yam chips

Castle (1993) stated that visual aids to learning are especially important in Africa because few children in Africa can travel far from their homes to see the world about which they have to learn. Only a few homes have books and pictures that children can study in leisure time. Black ink consists of a number of differently coloured substances mixed together Using paper chromatography the components can be separated into a series of concentric bands by alcohol as solvent as it spreads from the centre of the paper. The colour band furthest from the centre of the filter paper contain the substance that is the least strongly adsorbed, and that remaining in the centre of the filter paper contain the substance most strongly adsorbed (Holderness and Lambert, 1976). In this study when black ink from BIC pen was applied to the stick of chalk, cassava and yam chips and placed in water, for chalk stick yellow colour moved out first followed by red (deep pink) then blue - black colour. This implies that yellow colour is least adsorbed by chalk stick followed by red colour and then blue-black colour For cassava and yam chip, the ink separated with red colour first followed by blue-black colour and the separation was very slow. Thus, in the case of yam and cassava chips only two colours were separated and in this case red was the lesser adsorbed by the adsorbents followed by blue-black colour. Vancleavis (1997) asserted that each separated part of a mixture can be identified by its colour and flow rate (R). The separation is due to capillary action and solubility (Kneen *et al*, 1972). When locally manufactured alcohol (akpeteshie) was used in place of water, black ink from BIC pen separated with more distinct colour bands and the separation was very fast. Hence, it can be argued that alcohol did dissolve the components of the mixture better than water. It may also be as a result of lesser adhesive forces between the mixture molecules and that of alcohol compared to that of the mixture and water molecules. The results also showed that when alcohol was used the colour bands were most distinct and the separation was fastest for chalk stick compared to cassava and yam chips. Here again it can be argued that using alcohol as the solvent the components of black ink are not strongly adsorbed to chalk stick proving to be the best for adoption. When ink with trademark name KOFA was used and the chalk stick placed in water, red colour moved first followed by blue-black colour. For cassava and yam chip, KOFA ink could not separate into any visible components. In alcohol, KOFA ink did not show any distinct colour separation for any of the stationary phases.

(ii) Use of syringe columns

Kneen, Rogers, and Simpson (1972) observed that a glass tube packed with silica gel can serve as a column for column chromatography and water used as the mobile phase. In this case any mixture applied to the top of the column will move down it at a rate determined by its partition coefficient between the moving phases When the right rate has been chosen the material moves down the column as a narrow band at a speed. which depends on its partition coefficient. If several different materials are applied in the form of a mixture to the top of the column, then they will move down the column at different speeds. They emerge from the bottom of the column as eluted materials at different times and are collected in different vessels If they are coloured, their progress down the column can be seen but if this is not the case, then their emergence from the column must be detected by different means. The column chromatography under this study showed similar results as stated by Kneen *et al* (1972). When black ink from BIC pen was used with water as the mobile phase and maize powder as stationary phase, orange colour separated first, followed by red, then black and they all moved down the column. It was the same case for chalk powder as stationary phase. In both cases separation delayed. However, separation through starch powder started earlier and the order of separation was yellow, red, blue then green down the column. Here it can be said that the components of BIC black ink moving along with water as mobile phase through starch powder have lesser affinity for starch powder than maize powder and chalk powder When, alcohol was used as mobile phase with maize powder and starch powder as stationary ases, yellow separated first followed by red then blue black. For chalk powder as stationary phase and alcohol as mobile phase the order was: yellow, light green, red then blue - black. Here it seems chalk powder as stationary phase and alcohol as mobile phase produced the best result where more colour separation took place.

When KOFA type of ink was used as the mixture and water as mobile phase the order of colour separation along chalk, maize and starch was: red, and then blue-black. However, there was no distinct colour separation for starch and chalk when alcohol was used, but red colour, followed by blue-black colour was observed along maize powder. For either water or alcohol as mobile phase the red colour was very distinct when maize powder was used as stationary phase. In all cases the colour drained down into containers put under the column one after the other at different times. According to Ellington, Percival, and Race (1984) a resource in education is a system, set of materials or situation that is deliberately created or set up to enable an individual student to learn. The model under this study meets the qualities proposed by Ellington *et al* (1984) such that it can be readily available, allows students self-pacing, and it meets the needs of the students.

(iii) Trial Results

According to Garg and Garg,(2001) projects and models induce the young minds to develop scientific temper and harness their skills. Race (1994) observed that people learn by having a go themselves. They learn by doing. They learn by getting things right. However, they learn even more by getting things wrong and getting feedback on what was wrong. Sharma (2001) stated that children tend to be naturally creative, but their creativity is dampened as a result of authoritarian system of education. Teachers and educators have a great responsibility to children and society to see that creative ability is manifested to the maximum of the individual potential. Creativity cannot be taught but can be developed in the children by providing situations that demand imagination, originality and problem solving. The discovery or problem solving method of teaching is very helpful in developing creativity in children. This could be done through providing intellectual atmosphere in the class, free expression, proper physical environment such as enough space and materials to work with. The material and equipment need not be highly sophisticated. A large number of experiments and investigations can be done by using simple improvised apparatus. What is important is that the children should be encouraged to design and improvise the basic equipment themselves (Sharma, 2001). The results in Table1 showed that few students had very limited knowledge about the topic chromatography before it was introduced to them in class. Generally, the highest mark obtained was 44% and the lowest was zero percent. In all, 28.28% in school A and 24.75% in school B had prior knowledge of the topic before the teaching was done (those who scored marks above zero percent for the pretest). Also, 77.72% in school A and 75.25% in school B scored zero percent for the pretest.

Table 1: Performance of students before the topic was taught in class

Sample Results					% Of students with Prior Knowledge	Percentage scoring zero out of the total number of students in school
School	Total in School	Sample size (n)	% Marks			
			0 - 40	41 +		
A	99	60	81.67 (49)	18.33 (11)	28.28 (28)	77.72 (71)
B	101	60	78.33 (24)	21.67 (13)	24.75 (25)	75.25 (76)

Reece and Walker (1994) observed that anything that is used to augment teaching and learning strategy could be termed as learning aid or resource. Learning aids use all the five senses. They use hearing through audio aids like the cassette recorder, sight through visual aids like charts and posters and printed resources like handouts and books, touch through resources like specimens and models, and also to a lesser extent, taste and smell in, for example cookery. More than one sense can be combined in visual aids such as a film or a tape-slide presentation that contains both hearing and sight (Reece and Walker, 1994). In this study the results after using the models in teaching are presented in Figure 1. In school A there was no distinction and 6.67% of the students obtained excellent in the class in which the models were not used. However, 16.67% distinction and 23.33% excellent were recorded for the test experiment. No student failed in both cases (Fig 1a). The difference between the means is very highly significant ($t = 3.53$, $P < 0.001$). In school B also, 0% distinction and 6.67% excellent were recorded for the control experiment whilst 16.67% distinction and 16.67 excellent respectively were recorded for the test experiment. Whilst 10% of the control failed there was no failure for the test experiment (Fig 1b). The differences between the means were very highly significant ($t = 3.50$, $P < 0.001$) (Table 2).

Bishop (1986) observed that teaching – learning material must cater for three rates of learning, namely, fast, average and slow and for three styles, namely, auditory, visual/graphic and verbal/written for each of the subject areas. The results showed that the models enhanced the understanding of the topic in those classes that they were used compared to those classes that they were not used. These observations are in line with what Reece and Walker (1994) wrote that well designed aids should promote perception, understanding, reinforcement, retention, motivation and arousing of interest, providing variety and promotes effective use of time that students spend in learning. Reiss (1993) indicated that school science teaching should enable all pupils to understand the natural world in which they live. The teacher must consider the pupils' existing knowledge. Presumably, the choice of a set of local specimens which interact positively with traditional beliefs can lead to significantly more correct scientific observations (Reiss, 1993). A teacher who uses the textbook as the entire teaching guide limits the variety and quality of instruction. Adding community resources enhances learning opportunities, allows experiences that address goals of a comprehensive science education programme, provides the link between the students' present and future experiences, and makes the teaching process personal for both the student and the teacher (Martin Jr., Sexton, Wagner and Gerlovich, 1994) . Thus, in this study the better performance of students in the experimental group would have been as a result of the interaction and imprint students had when they were taught using the models made mainly from local materials. The results also showed that performance in school A is better than in school B. Nacino-Brown, Oke, and Brown (1992) observed that for the effective use of models the teacher needs to make sure that everybody can see the model being presented. Also, the teacher needs to plan for the students' participation. The students should be given the opportunity to handle and examine the material being studied. According to Croll and Nigel (1997) good management of appropriate resources can undoubtedly enhance learning. Hence, the differences in the performance of the two schools may be due to differential effectiveness of the use of the models by the teachers or due to differential academic standards of students in the two schools. However, neither the differences between the means of the control ($t = 0.84$, $p > 0.05$) nor between the means of the test experimental ($t = 0.68$, $p > 0.05$) results of the two schools was significantly different (Table 2).

Table 2: Mean percentage marks when the models were used

SCHOOL	CONTROL	TEST EXPT.	SD	t-TEST
A	58.73	72.20	14.89	3.53
B	55.70	69.43	16.96	3.50

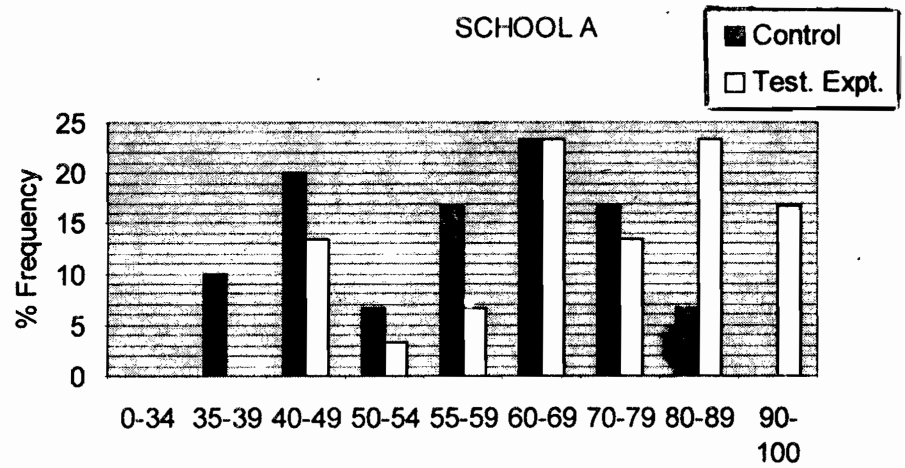

Fig. 1a: Mark distribution of students when the model was used

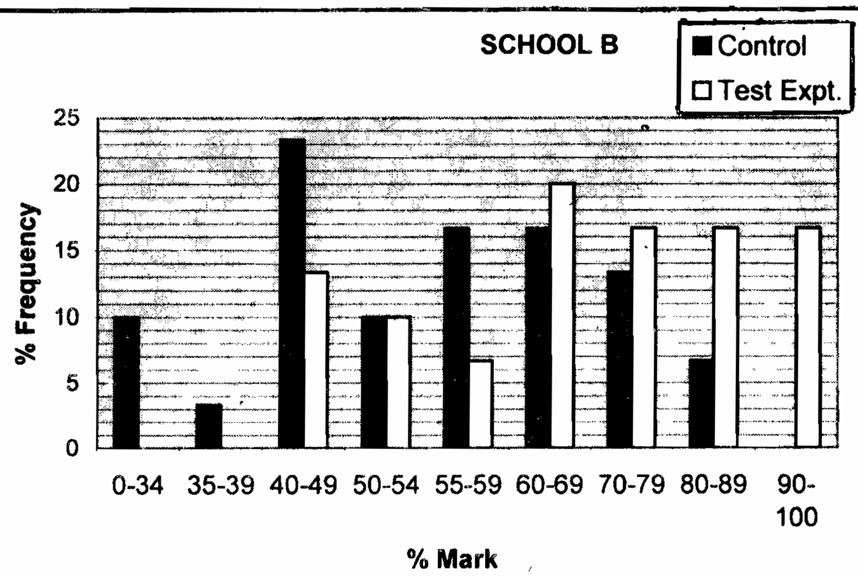

Fig. 1b: Mark distribution of students when the models were used

RECOMMENDATIONS

The results showed that the components of BIC black ink can separate into some component when chalk stick, yam chip, or cassava chip is used as stationary phase whilst water or alcohol (Akpeteshie) is used as mobile phase. However, more colour bands can be seen when chalk stick is used compared to yam or cassava chip. Also, the results showed that when alcohol was used the colour bands were most distinct and the separation was fastest for chalk stick compared to cassava and yam chips. Hence, it is recommended that basic schools that do not have equipment for performing chromatography experiments can use chalk stick as stationary phase and locally manufactured alcohol as mobile phase to separate the components of dyes especially black ink. However, in the absence of the alcohol water can be used. Similarly, in the absence of chalk stick cassava or yam chip can be used

From the results it can be said that syringe can be used as column to perform column chromatography to eparate dyes especially BIC black ink. Chalk powder as stationary phase and alcohol as mobile phase have been recommended for column chromatography because they produced the best result where more colour separation took place at faster rate. KOFA type of ink did not produce promising results. The trial results showed that the models enhanced the understanding of the topic when they were used This further suggests that the models can be used to demonstrate chromatography. Hence, basic level science teachers in Ghana are encouraged to use it for teaching chromatography

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REFERENCES

Andrew, J. and Rispoli, P., 1991. Chemistry in Focus. London: Hodder &Stoughton.

Bishop, G., 1986. Innovation in Education. London. Macmillan Educations Ltd

Bouma, H; Udo, R. and Wiederholt, E., 1988. Low cost chromatography for air analysis. Chemistry Education/October-December: 57 – 61

Castle, E. B., 1993. Principles of Education for Teachers in Africa. Nairobi: Oxford University Press, pp. 89 – 92.

Chandrasekaran, J., 2001. Chemistry of Colours. Resonance: 66 – 75

Croll, P. and Nigel H., 1997 Effective Primary Teaching. Research – based Classroom Strategies. London: David Faulton Pub.

Ellington, H.; Percival, F. and Race, P., 1984. Handbook of Educational Technology, (3rd ed.). London: Kogan Page Ltd.

Ellington, H. and Race, P., 1985. Producing Teaching Materials (2nd ed.). London: Kogan Page Ltd.

Garg, L C. and Garg, A., 2001. Science Projects. New Delhi: Pustak Mahal Pub.

Holderness, A. and Lambert, J., 1976. A new certificate chemistry, London Heinemann Educational Books.

Hordzi, W. H K and Mensah, B. A., 2003. Classroom: Inexpensive Models for Teaching Atoms in Junior Secondary School Level of Education Global Journal of Educational Research, 2(1&2): 33-40.

Kneen, W. R., Rogers, M. J. R; and Simpson, P., 1972. Chemistry facts, patterns and Principles, (Revised edition), London: Addison Wesley Publishers Ltd.

Marov, S. and Stedjee, B., 1994. Experiments in Basic Chemistry, (3rd ed). New York: John Wiley &Sons Inc.

Martin Jr., R.; Sexton, C., Wagner, K and Gerlovich, J., 1994. Teaching Science for All Children. Boston: Allyn and Bacon.

Nacino-Brown, R; Oke, F O, and Brown, D. P., 1992. Curriculum and Instruction: An Introduction to Methods of Teaching London. Macmillan Pub.

Race, P., 1994 The Open Learning Handbook: Promoting quality in designing and Delivering Flexible Learning, (2nd ed.) London Kogan Page Ltd.

Reece, I. and Walker, S., 1994. A practical guide to teaching, training and learning. (2nd ed.). Sunderland Tyne: Business Education Pubs.

Reiss, M. J., 1993. Science Education for Pluralist Society. Buckingham: Open University Press.

Sharma, R. C., 2001. Modern Science Teaching, New Delhi: Dhanpat Rai Pub. Co.,

Vancleavis, J., 1997 Janice Vancleavi's A+ Projects in Chemistry, Winning Experiments for Science Fairs and Extra Credit. New Delhi: Pustak Mahal.