Portable T-Shirt Printing Machine

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Abstract
T-shirt printing is one of the occupations of the youth in the Ho Municipality of Ghana. Various methods of printing such as dye sublimation, heat transfer and screen printing are employed to print t-shirts in Ghana. However, screen printing is the most popular method in Ghana. It is easy to use and less expensive. Despite the fact that the screen printing method is the most preferred in Ghana, its processes come with challenges. The printing process is slow and the products that are churned out are of low quality. And in order to minimise the problems that local printers encounter during screen printing, the "Portable T-shirt Printing Machine" has been developed. The machine which is manually operated comes with an adjustable squeegee, leather padded table, an adjustable metallic frame which holds the screen during printing and a magnetic holder which holds the frame taut during printing without the help of a second person. The squeegee can be moved manually by the help of a bearing and a hollow pipe. The squeegee blade which is made of rubber can easily be removed and washed after each printing session. The Portable T-shirt Printing Machine which is 75cm long, 45cm wide and 12cm high can be carried easily and printing can be done anywhere whether there is electricity or not. The adjustable metallic frame which holds the frame can be adjusted to suit any screen size; ranging from (40 cm by 40cm) to (15cm by 15m) or even smaller screens. The research design adopted for the study is the qualitative (descriptive) approach. The sample population for the study is 108 representing 30% of the target population. The data collecting instruments used were interview, observation and questionnaire. The main findings of the study were that, the speed of the traditional screen printing process can be increased when a machine is developed. Also, the fastness and efficiency of the t-shirt printing process have a direct relation with the income earned. It is therefore recommended that the "Portable T-shirt Printing Machine" is adopted by the local printers to enhance their occupation. It is also recommended that the metal parts of the machine are oiled regularly to prevent friction and rusting. Furthermore, a challenge is thrown to prospective researchers to conduct a research into the automation of the "Portable T-shirt Printing Machine" so as to increase its speed.
Keywords: Squeegee, Sublimation, T-shirt, Heat Transfer, Screen Printing and Portable.

1.0 INTRODUCTION
Screen printing is a printing technique whereby a mesh is used to transfer ink onto a substrate, except in areas made impermeable to the ink by a blocking stencil. A blade or squeegee is moved across the screen to fill the open mesh apertures with ink, and a reverse stroke then causes the screen to touch the substrate momentarily along a line of contact. This causes the ink to wet the substrate and be pulled out of the mesh apertures as the screen springs back after the blade has passed.

Screen printing is also a stencil method of print making in which a design is imposed on a screen of polyester or other fine mesh, with blank areas coated with an impermeable substance. Ink is forced into the mesh openings by the fill blade or squeegee and by wetting the substrate, transferred onto the printing surface during the squeegee stroke. As the screen is removed from the substrate, the ink remains on the fabric making beautiful patterns. Screen printing is also known as **serigraphy** or serigraph **printing**. One colour is printed at a time, so several screens can be used to produce a multicoloured image or design. (Wikipedia)

Adu-Akwaboa (1989) defines screen printing as a process of transferring a good paper design onto a fabric. According to him, this is achieved by transferring the design onto a tracing paper (kodatrace) with opaque ink. Each colour on the design must have a separate tracing paper. In other words, each colour will have a separate screen for printing. A photographic method is used to transfer the design from the tracing paper to the screen with the help of light. During the photographic development of the screen, the opaque areas are left open for dye penetration while the negative areas are blocked to avoid dye penetration.

Tortora and Merkel (2005), explain the process of screen printing as a method of printing whereby the patterns are blocked out on a mesh fabric or screen so that when the colour is squeezed through, it will penetrate the unblocked areas. The colour paste is forced through the screen by a squeegee. Each colour in the pattern requires a separate screen.

Screens can be used to print beautiful designs on any smooth and absorbent material be it fabric, ceramic wares, paper, sacks, bags and t-shirts. The screens which are normally made of soft wood and mesh come in various sizes depending on the size of the design to be created and the surface area to be covered. T-shirt printing has become the preoccupation of most local printers because of its high demand and accessibility. Social

groupings such as school leavers, community associations and public institutions put on T-shirts as a way of identification and socialization.

Despite the easy accessibility of tools and materials for t-shirt printing, the processes involved in the printing are tedious. Two people are normally involved in the printing. One person holds the screen while the other pulls the squeegee to print the design. After printing, the squeegee is held in the hand for the next printing session but if care is not taken, the printing ink can soil the hands which can easily be transferred onto the t-shirt thereby making it dirty. In the event where there is no person to assist the printer, printing becomes difficult and this can result in defects.

To mitigate the problems associated with T-shirt printing, the "Portable T-shirt Printing Machine" has been designed. It comes with a metallic frame which holds the screen, a detachable padded printing table and a free-moving and adjustable squeegee. The "Portable T-shirt Printing Machine has the capacity to print a large number of t-shirts due to its fastness. It is portable and can be easily carried along and printed anywhere. The machine is convenient to print by one person. Thus, there is no need for a second person. The machine is therefore economical and less stressful.

2.0 REVIEW OF RELATED LITERATURE

In order to strengthen the theoretical framework of this paper and to establish its uniqueness, frantic efforts have been made to review related literature from various sources such as the internet, books and monograms. The review was done under the following sub headings: Overview of Screen Printing, History of Screen Printing, T-shirt Printing and T-shirt Printing Machines.

2.1 Overview of Screen Printing

Screen printing is arguably the most versatile of all printing processes. It can be used to print on a wide variety of substrates, including paper, paperboard, plastics, glass, metals, fabrics, and many other materials. Some common products from the screen printing industry include posters, labels, decals, signage, and all types of textiles and electronic circuit boards. The advantage of screen printing over other print processes is that the press can print on substrates of any shape, thickness and size.

A significant characteristic of screen printing is that a greater thickness of the ink can be applied to the substrate than is possible with other printing techniques. This allows for some very interesting effects that are not possible using other printing methods. Because of the simplicity of the application process, a wider range of inks and dyes are available for use in screen printing than for use in any other printing process.

According to Adu-Akwaboa (1994), screen printing is the process of transferring designs from screens onto a textile material with print paste. He further explains that before a design is printed, it is transferred onto a well stretched screen so that all but the design is covered by a resist material.

Screen printing is basically a form of stencil printing. The screen consists of a synthetic fibre or metal gauze stretched taut over a frame. Parts of the gauze have the holes blocked off and the printing paste is forced through the open areas by a rubber blade called a squeegee. In hand screen printing, the fabric is stuck to the printing table, which is covered with a resilient felt, wax cloth or rubber material. Each screen is placed on the fabric in turn; the paste is then applied to one end of the screen and the squeegee drawn by hand through the paste and across the screen, forcing it through the open mesh areas onto the fabric beneath. (Tortora, 1992)

Screen printing is that aspect of textile printing which involves the application of colour to a fabric in definite patterns or designs. In properly printed fabrics, the colour is bonded with the fibre, so as to resist washing and friction. (Wikipedia)

Applying coloured patterns and designs to decorate a finished fabric is called 'Printing'. In a proper printed fabric, the colour is affixed to the fibre, so that it may not be affected by washing and friction. Whether a fabric is dyed or printed can be known by examining the outline of the design. On a printed fabric, the outline of a design is sharply defined on the outer side. (www.teonline.com)

According to Wikipedia, there are various terms used to describe screen printing. Traditionally, the process was called *screen printing* or *silkscreen printing* because silk was used in the process prior to the invention of polyester mesh. Currently, synthetic threads are commonly used in the screen printing process. The most popular mesh in general use is made of polyester. There are special-use mesh materials of nylon and stainless steel available to the screen printer. There are also different types of mesh size which will determine the outcome and look of the finished design on the material.

Screen Printing involves the production of a predetermined coloured pattern on a fabric, usually with a definite repeat. It can be described as a localised form of dyeing, applying colorant to selected areas of the fabric to build up the design. Screen Printing, like Textile dyeing, is a process for applying colour to a substrate. However, instead of colouring the whole substrate (cloth, carpet or yarn) as in dyeing, print colour is applied only to defined areas to obtain the desired pattern. This involves different techniques and different machinery with respect to dyeing, but the physical and chemical processes that take place between the dye and the fibre are

analogous to dyeing. (Textile learner, 2011)

2.2 History of Screen Printing

Screen printing first appeared in a recognizable form in China during the Song Dynasty (960–1279 AD). It was then adapted by other Asian countries like Japan, and was furthered by creating newer methods.

Screen printing was largely introduced to Western Europe from Asia sometime in the late 18th century, but did not gain large acceptance or use in Europe until silk mesh was more available for trade from the east and a profitable outlet for the medium discovered.

Early in the 1910s, several printers experimenting with photo-reactive chemicals used the well-known actinic light–activated cross linking or hardening traits of potassium, sodium or ammonium chromate and dichromate chemicals with glues and gelatin compounds. Roy Beck, Charles Peter and Edward Owens studied and experimented with chromic acid salt sensitized emulsions for photo-reactive stencils. This trio of developers would prove to revolutionize the commercial screen printing industry by introducing photo-imaged stencils to the industry, though the acceptance of this method would take many years. Commercial screen printing now uses sensitizers far safer and less toxic than bichromates. Currently, there are large selections of pre-sensitized and "user mixed" sensitized emulsion chemicals for creating photo-reactive stencils.

A group of artists who later formed the National Serigraphic Society coined the word Serigraphy in the 1930s to differentiate the artistic application of screen printing from the industrial use of the process. "Serigraphy" is a compound word formed from Latin "sēricum" (silk) and Greek "graphein" (to write or draw).

The Printers' National Environmental Assistance Center says "Screen printing is arguably the most versatile of all printing processes." Since rudimentary screen printing materials are so affordable and readily available, it has been used frequently in underground settings and subcultures, and the non-professional look of such DIY culture screen prints have become a significant cultural aesthetic seen on movie posters, record album covers, flyers, shirts, commercial fonts in advertising, in artwork and elsewhere.

1960s to present

Credit is generally given to the artist Andy Warhol for popularising screen printing as an artistic technique, identified as serigraphy, in the United States. Warhol was supported in his production by master Screen Printer Michel Caza, a founding member of Fespa, and is particularly identified with his 1962 depiction of actress Marilyn Monroe, known as the Marilyn Diptych, screen printed in garish colours.
Sister Mary Corita Kent, gained international fame for her vibrant serigraphs during the 1960s and 1970s. Her works were rainbow coloured, contained words that were both political and fostered peace and love and caring.

American entrepreneur, artist and inventor Michael Vasilantone started to use, develop, and sell a rotatable multicolour garment screen printing machine in 1960. Vasilantone later filed for patent on his invention in 1967 granted number 3,427,964 on February 18, 1969. The original machine was manufactured to print logos and team information on bowling garments but soon directed to the new fad of printing on T-shirts. The Vasilantone patent was licensed by multiple manufacturers, the resulting production and boom in printed t-shirts made this *garment* screen printing machine popular. Screen printing on garments currently accounts for over half of the screen printing activity in the United States.

Graphic screen printing is widely used today to create mass or large batch produced graphics, such as posters or display stands. Full colour prints can be created by printing in CMYK (cyan, magenta, yellow and black ('key').

Screen printing lends itself well to printing on canvas. Andy Warhol, Arthur Okamura, Robert Rauschenberg, Roy Lichtenstein, Harry Gottlieb and many other artists have used screen printing as an expression of creativity and artistic vision.

According to Adu-Akwaboa 2001, records have it that the art of printing designs or patterns on fabric has been in existence since prehistoric times. Mention can be made of Africa, Greece, Peru, China, France, Mexico, Scandinavia and England for their works in this art. There are various opinions about the origin of printing. While some school of thought believe that it started from the river valleys of China, India and Mesopotamia, another believes that it started independently in various parts of the world. Archaeologists say that fabrics from natural fibres were produced more than eighty-five hundred years ago, in Catal Huyuk in present-day Turkey. Whichever is the case, the textile industry which started at home as an art and craft industry has now developed into multinational corporations.

When the first man realized his nakedness, he used leaves to cover his private parts. Man later found out that animal skins acquired through hunting and barks of trees were stronger for the covering of the body. The main purpose for the use of these materials was protection against cold and heat. Later, with civilization, man did not only think about protection but also comfort and the aesthetic value of the coverings and these necessitated the decoration of these pieces with dyes before they were used. This brought about the art of creating patterns or designs on fabrics through various means.

2.3 T-Shirt Printing

A **t-shirt** is a style of unisex fabric shirt, named after the T shape of the body and sleeves. It is normally associated with short sleeves, a round neckline, known as a *crew neck*, with no collar. T-shirts are generally made of a light, inexpensive fabric, and are easy to clean.

Typically made of cotton textile in a stockinette or jersey, knit, it has a distinctively pliable texture compared to shirts made of woven cloth. The majority of modern versions have a body made from a continuously woven tube, on a circular loom, so that the torso has no side seams. The manufacture of t-shirts has become highly automated and may include fabric cutting by laser or water jet.

The t-shirt evolved from undergarments used in the 19th century, and in the mid-20th century transitioned from undergarment to general-use casual clothing.

Printed t-shirt is a favourite clothing among youngsters. They often use their clothing to portray their personality and style. Printed t-shirts with different designs and patterns and vibrant colours help them just with that. With changing time and fashion, these t-shirts have also seen a lot of changes. There have been many innovations and technological advances in t-shirt printing that have made this clothing even more modern and popular among people of all age groups.

2.3.1 Printing Methods

There are many other methods of t-shirt printing such as airbrush, screen printing embroidery, applique, impressing or embossing, heat transfers, or dye-sublimation transfers. Laser printers are also used, first to print on plain paper using a special toner which contains sublimation dyes and then permanently heat-transferring it on t-shirts. The type of method you select depends largely on what design you want to print and the number of t-shirts to be printed.

2.3.1.1 Screen Printing

Screen printing (sometimes called silk screening, or serigraphy) is a fantastic artistic technique which is especially useful for printing onto a t-shirt. The process is easy, versatile and relatively cheap so everyone can use it. The Screen printing process is the oldest technique and gives you many custom options. It is also very durable.

2.3.1.2 Dye Sublimation

To print full colour designs on light coloured t-shirts, the dye sublimation is the best method. However this method is a bit more expensive than the others, it has no feel to the design and it is a little difficult to master than inkjet heat transfers. Dye sublimation cannot be used for most of the natural fabrics and is mostly suitable for fabrics like polyester.

2.3.1.3 Computerized Printing

Using computerized printing methods for printed t-shirts is best for small orders as this method is suitable to print complex designs and multi colours. Different printed t-shirts can be easily customized using this method. Printing methods using vinyl cutters is yet another technique to print customised t-shirts in small quantity. In this method, a machine is used to cut out designs on special solid colour vinyl sheets. Then heat is used to stick- cut vinyl onto a paper and later heat pressed on the fabric. This type of print is of high quality, durable and can be used easily to customize different t-shirts which is great for small orders.

2.3.1.4 Direct Printing

Another simple method of printing which is most commonly used at homes is direct printing on the fabric. In this method different types of inks are directly applied onto the cloth by hand to get the desired results. This method reduces various steps included in other printing methods. The design patterns in direct printing does not have heavy feel like screen printing. However it is a little difficult to cover a large area of the cloth in this method and the cloth itself is the brightest part of the design.

2.4 T-shirt Printing Machines

There are several machines for printing t-shirts. They come in various forms and shapes. DTG printers are the most common and widely used. They include the Viper, M2 and M4 DTG printers.

1. Viper – **the Viper is the most budget friendly professional DTG Printer on the market** with the kind of features and flexibility that make it a favourite for start ups and big custom t-shirt shops as well. Many competitive t-shirt printers only print on white or light coloured textiles. The Viper, like all of the DTG Printer product line, prints on both dark and light garments – and produces simply amazing quality images. Other Viper features include:

- 4-2-1 Platen System – which means that you can actually print on up to 4 garments at a time. The "4" might be a left chest logo, small design or children's wear job. The "2" means that you can print on 2 adult sized tees at once and the 1 will actually allow you to print a HUGE 16.5" X 29" image. That's a big print on a BIG t shirt, or beach towel, or hoodie.
- WIMS Filter – direct to garment printers that print on dark tees do so by laying down a layer of white ink first, then printing on top of that white image. If it didn't do this, then all of your printed images

would be tinted by the colour of the t-shirt itself. BUT, white ink has a tendency to settle and separate so it needs to be agitated or circulated on a regular basis. ALL of DTG brand printers do this with the White Ink Management System to avoid stopping printing and agitating the ink manually during the day.

2. M2 – **The M2 is the most popular t-shirt printing machine in the line-up today**. It hits the sweet spot between the pricing of the Viper, and the volume capacity of its big brother, the M4. The M2 is the first DTG printer built from the ground up to print t-shirts. Up until the M2, garment printers had been modified large format Epson paper printers. Where the M2 is superior to the Viper is in the way it prints 2 garments at a time. The Viper works on a conveyor style system that actually prints the complete image on one shirt, then advances and does the next. The M2, on the other hand, runs the 2 platens through simultaneously so it actually prints both tees at once. This results in a faster print time with the same great quality output, and in the custom t-shirt business FASTER is BETTER! Here's what else makes the M2 stand out:

- Software Bundle – There is a suite of expensive software that usually needs to be added to a t-shirt printing machine purchase. The software that most manufacturers recommend include their own option RIP software, Photoshop, Illustrator, Corel Draw or other graphics applications that you either have to buy or subscribe to on a monthly basis. The M2 actually comes with the most current version of RIP pro and a graphics application called Gimp.

3. M4 – **The M4 has the same print engine and body as the M2, but has been modified to utilize 4 platens instead of 2**. What does that mean? That you can print on 4 or more t-shirts at once! This printer provides the lowest "interface time". Interface time is how long an operator has to interact with the machine during a given day, or job. For example, most direct to garment printers on the market today on print on 1 t-shirt at a time. This means that the operator has to load a job into the software, put the t-shirt on the platen, then wait for it to print and take it off, put the next one on, etc. With the M4 and the Rip Pro software, you can actually set up multiple jobs and run different jobs at the same time. Basically, you load a series of jobs in the software set up 4 shirts and walk away while they all print. Make phone calls, close sales, do the books, or whatever else you need to do while those 4 shirts print. No need to stand, watch and WAIT. (www.ebay.com)
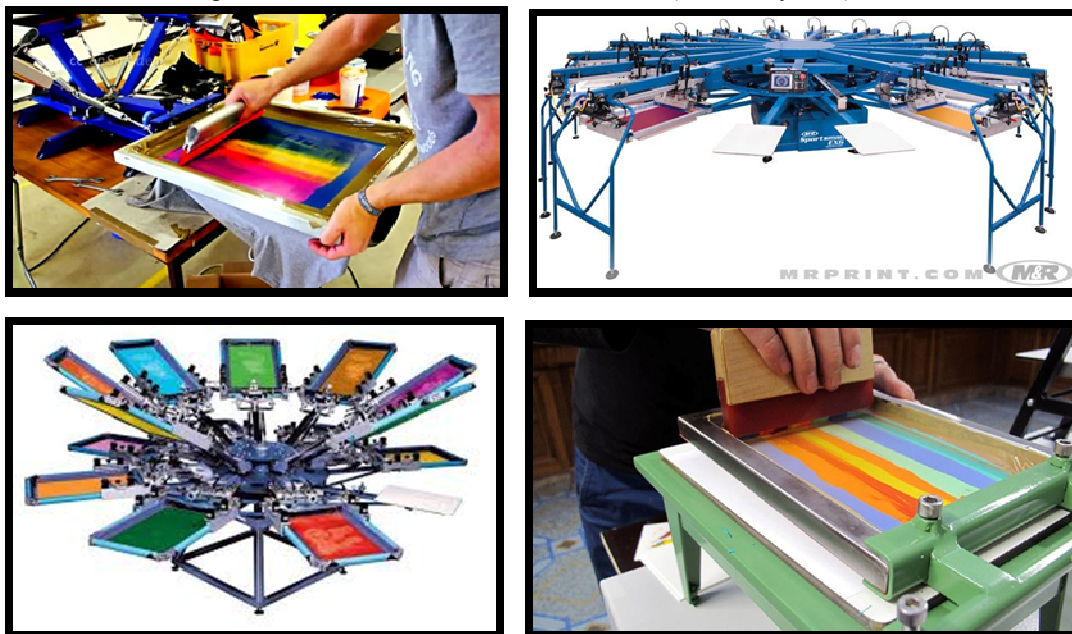

Plate 1: some t-shirt printing machines

2.5 Summary of Discussions

Literature reviews are basically conducted to study and compare existing literature with new research findings to create a gap for further research. The works of various authors reviewed point to the fact that screen printing is the most preferred method for printing on t-shirts all over the world. This stems from the fact that, screen printing is the most convenient and inexpensive method that can be used by anybody provided the person is given some form of training. The other methods: heat transfer, dye sublimation transfer and embossing are difficult to learn and expensive to produce. It is against this backdrop that the researchers of this paper thought it wise to base their work on screen printing machines. A critical review of the hand screen printing industry in Ghana reveals the difficulties that local screen printers face as a result of the use of crude tools and equipment. It has been observed that hand printing process is slow and full of deficiencies. To solve these teething problems, the "Portable T-shirt Printing Machine" has been invented by the authors of this research paper. The next section

of the paper will dwell on the methodology.

3.0 METHODOLOGY

This part of the paper presents the various methods and procedures used in collecting, collating and synthesizing data for the study. It is sub-divided into Research Design, Target Population, Sampling Techniques, Types of Data and Data Collection procedures.

3.1 Research Design

The research study was a descriptive one. This type of research portrays an accurate profile of persons, events or situations. The descriptive research therefore offers the opportunity to elaborate and tap the diverse views of respondents. (Amankwa *etal,* 2015). In this study, it was used substantively to describe the various processes involved in the manufacture of the "Portable T-shirt Printing Machine," from the design stage through to finishing stage.

3.2 Target Population

The Target Population for the study includes Way-Side Artists in the Ho Municipality, Visual Art students in selected SHS in Ho and its environs, Industrial Art students of Ho Technical University, Visual Art Tutors of selected SHS in Ho and its environs and Art Lecturers of Ho Technical University. The table below shows the numerical representation of the Target Population:

Table 1: Target Population

NUMBER	RESPONDENTS	POPULATION
1	Way-Side Artists	30
2	Visual Art students of selected SHS in Ho and environs	60
3	Industrial Art students of HTU	245
4	Visual Tutors	14
5	Art Lecturers	11
	Total	**360**

Source: Field Data, June 2017

3.3 Sampling Techniques

By the nature of this research, it was not possible to include all available population for study, therefore only the sample population was studied. The sample population includes selected Way-Side Artists in the Ho Municipality, selected Visual Art students of some selected SHS in Ho and its environs, selected Industrial Art students of Ho Technical University, selected Visual Art Tutors of some selected SHS in Ho and its environs and some selected Art Lecturers in Ho Technical University. The Sample Population represents 30% of the Target Population (360) which gives a sample size of (108) respondents as shown in table 2 below:

Table 2: Sample Population

NUMBER	RESPONDENTS	POPULATION
1	Way-Side Artists	9
2	Visual Art students of selected SHS in Ho and environs	18
3	Industrial Art students of HTU	73
4	Visual Tutors	5
5	Art Lecturers	3
	Total	**108**

Source: Field Data 2017

3.4 Types of Data

Two forms of data were collected for the study. These were: primary and secondary data. Primary data relevant to the study were collected from the field by the help of research tools. The research tools used for the study were: observation, interview and questionnaire. Secondary data were collected from books, publications, catalogues, periodicals, newsletters, brochures, journals, magazines, monograms, charts and encyclopaedias.

3.5 Data Collection Procedures

For a study like this, the use of the following research instruments: observation, interview and questionnaire was indispensable. They all played vital roles in eliciting valid data for the study.

3.51 Observation

The natural way of gathering information is by observation and it is most direct in terms of studying people when one is interested in the explicit behaviour and the result achieved or obtained is real and precise through

mechanical and electronic means (Sidhu, 1984). By the nature of this study, the observational approach was very helpful in capturing the exact appearance of objects related to the study. It was used extensively to record the hand screen process and the state of printing machines in Ho and its environs. The researchers thus visited the Art Centres in the Ho Municipality and critically observed the screen printing process which forms the basis for this research.

3.52 Interview

 Interview which is more or less an oral questionnaire was used to obtain vital information from a section of the Sample Population. It was observed by the researchers that about 12% of the Sample Population could neither read nor write. Therefore in order not to side line any of the respondents, the interview approach was used. The use of interview also afforded the researchers the opportunity to seek the clarification of the same information in several ways at various stages of the interview, thus providing a check of the truthfulness of responses. An interview guide was prepared and administered to the interviewees at prior notice. It was observed that certain confidential information which could not be divulged by respondents when employing the other research tools were willingly given out; as the researchers took time to explain the questions more clearly to the interviewees just the way they wanted it.

3.53 Questionnaire

A questionnaire is a written or printed form of questions used in gathering information on some subject or subjects consisting of a list of questions to be submitted to one or more persons. (Agra *etal,* 2015). The researchers therefore used this research instrument to elicit written information from the Sample Population. 108 questionnaire copies were administered to the Sample Population made up of 9 Way-side Artists, 18 Visual Art students from selected SHS in Ho and its environs, 73 Industrial Art students of HTU, 5 Visual Art Tutors and 3 Art Lecturers. The questions bothered on the understanding of screen printing, t-shirt printing, uses of t-shirts, available screen printing machines and their efficiency.

3.6 Summary of Discussions

This section of the paper succeeded in presenting the various research methods adopted in collecting and synthesizing data for the study. It touched on the target population, data collecting procedures and sampling techniques adopted by the researchers. The next section will dwell on the data analysis and working procedures.

4.0 ANALYSIS AND INTERPRETATION OF DATA

This part of the paper presents the statistical analysis of primary data for the study. The study made use of pie charts, bar charts and tables to analyse data.

4.1 Demographic Characteristics of Respondents

The pie chart below displays the gender distribution of respondents. According to the chart, 51% the respondents are male while 49% are female. This points clearly to the fact that the gender orientation of the study area is evenly distributed.

Chart 1: Gender Distribution
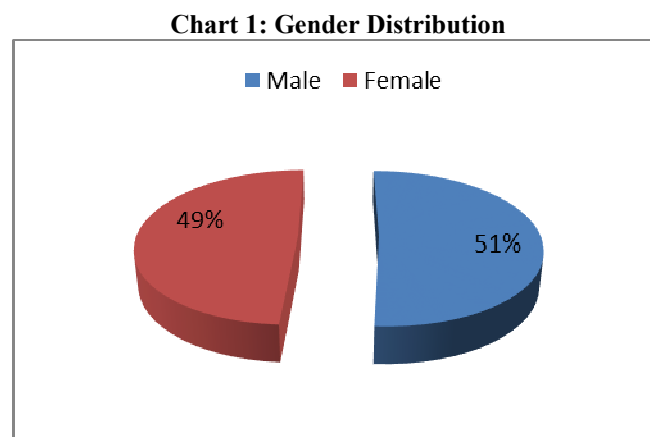
Source: Field Data, June 2017

4.12 Age Distribution of Respondents

The chart below shows the age distribution of respondents. It is clear from the chart that majority of respondents (40%) fall within the age bracket of 31- 40 years. This suggests the maximum involvement of the middle-aged youth in the study. Furthermore, 25% of respondents who participated in the study fall within the age bracket of 26-30. Also, 20% of the respondents are within the age bracket of 15-25.

Chart 2: Age Distribution
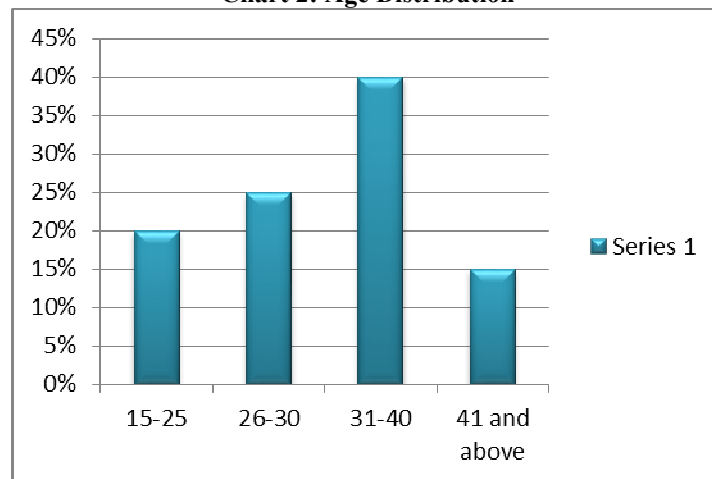
Source: Field Data, June 2017

4.13 Level of Education of Respondents

Chart 3 below displays the Educational Level of respondents who participated in the study. The results are skewed in a descending order. Majority of the respondents (38.1%) had tertiary education. This is followed by 30.5% of the respondents who attended Senior High School. As many as 17.80% of the respondents were JHS leavers while 13.6% of the respondents attended primary school.

Chart 3: Educational Level
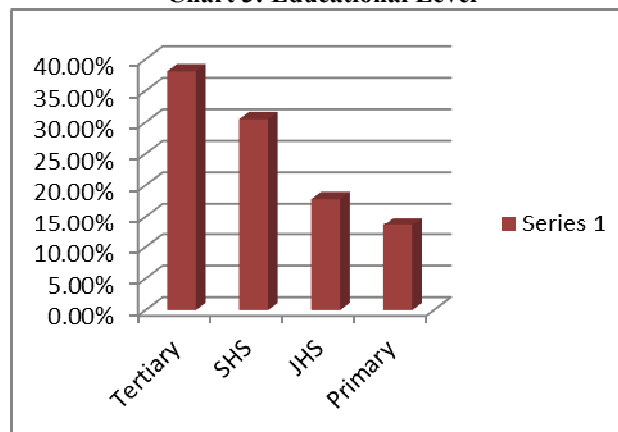
Source: Field Data, June 2017

4.14 Assessing Respondents' knowledge about Screen Printing

In table 3 below, the researchers sought to assess the knowledge of respondents on screen printing. The results are as follows: a whopping sum of 107 respondents representing 99.9% of the sample population gave a response in the affirmative while 1 respondent representing a negligible percentage of 0.1 gave "No" as an answer. It is obvious from the results that majority of the respondents chosen for this study have knowledge on the topic under discussion.

Table 3: Yes or No responses to the question: "do you have any knowledge about Screen Printing?

Responses	Frequency	Percentage (%)
Yes	107	99.9
No	1	0.1
Total	**108**	**100**

Source: Field Data, June 2017

4.15 Responses to the assertion: "Screen Printing is one of the methods of printing t-shirts"

Table 4 below presents the test results obtained from respondents concerning the statement that screen printing is one of the methods of printing t-shirts. 80 respondents representing 74.1% of the sample population agreed to the assertion while 3 respondents representing 2.8% of the sample population disagreed with the assertion. Furthermore, 25 respondents representing 23.1% of the sample population strongly agreed to the assertion.

Table 4: Responses to the statement: "Screen Printing is one of the methods of printing t-shirts

Responses	Frequency	Percentage (%)
Strongly disagree	0	0.0
Disagree	3	2.8
Neutral	0	0.0
Agree	80	74.1
Strongly agree	25	23.1
Total	**108**	**100**

Source: Field Data, June 2017

4.16 Responses to the statement: Manual Printing is bedevilled with problems

It is clear in table 5 below that almost all the respondents (98.15%) strongly agree that manual printing is bedevilled from problems. However, 2 of the respondents representing 1.85% of the sample population were neutral.

Table 5: Responses to the statement: Manual Printing is bedevilled with problems

Responses	Frequency	Percentage (%)
Strongly disagree	0	0.0
Disagree	0	0.0
Neutral	2	1.85
Agree	0	0.0
Strongly agree	106	98.15
Total	**108**	**100**

Source: Field Data, June 2017

4.17 Assessing the knowledge of respondents on the efficiency of Hand Screen Printing

Table 6 and 7 below display the responses of respondents on the efficiency of Hand Screen printing process. Table 6 collates the results of respondents on the speed of the Hand Screen printing Process while table 7 collates results on the assertion that the Hand Screen printing process is slow. In table 6, a good number of respondents (26) representing 24.07% of the sample population were neutral. They could neither agree to the assertion that: Hand Screen printing is fast nor slow. Interestingly, as many as 73 of the respondents representing 67.59% of the sample population disagreed with the assertion while a negligible number of 9 respondents representing 8.34% of the sample population agreed to the assertion. In table 7 below, 11 respondents representing 10.2% of the sample population disagreed with the assertion that Hand Screen printing is slow while as many as 78 respondents representing 72. 3% of the sample population agreed to the assertion. Additionally, 19 respondents representing 17.58% of the sample population strongly agreed to the assertion. Based on the responses given in table 6 and 7 below, a logical conclusion can be drawn that there is the need to do something to increase the speed of Hand Screen printing.

Table 6: Responses to the assertion: "Hand Screen Printing is fast"

Responses	Frequency	Percentage (%)
Strongly disagree	0	0.0
Disagree	73	67.59
Neutral	26	24.07
Agree	9	8.34
Strongly agree	0	0.0
Total	**108**	**100**

Source: Field Data, June 2017

Table 7: Responses to the assertion: "Hand Screen Printing is slow"

Responses	Frequency	Percentage (%)
Strongly disagree	0	0.0
Disagree	11	10.12
Neutral	0	0.0
Agree	78	72.30
Strongly agree	19	17.58
Total	**108**	**100**

Source: Field Data, June 2017

4.18 Relating the fastness of the t-shirt printing process to increased income

Table 8 below presents the test results of respondents on the assertion, "the fastness of t-shirt printing is directly linked to increased income. The results are as follows: a good number of the respondents (37) representing 34.26% of the sample population were neutral while 45 respondents representing 41.67% of the sample

population agreed to the assertion. Furthermore, 12 respondents representing 11.11% of the sample population strongly agreed to the assertion. However, 14 respondents representing 12.96 % disagreed with the assertion.

Table 8: Responses to the assertion: "the fastness of the t-shirt printing process is directly linked to increased income"

Responses	Frequency	Percentage (%)
Strongly disagree	0	0.0
Disagree	14	12.96
Neutral	37	34.26
Agree	45	41.67
Strongly agree	12	11.11
Total	**108**	**100**

Source: Field Data, June 2017

4.19 Exploring the defects associated with Hand Screen Printing
The table below displays some of the defects of manual printing outlined by respondents. Majority of the respondents (31) representing 28.70% of the sample population mentioned overlapping as one of the defects while 28 respondents representing 25.93% of the sample population stated bleeding as one of the defects. Additionally, 24 respondents representing 22.22% of the sample population stated that the screen dries quickly due to slow printing. Furthermore, 15 respondents representing 13.89% of the sample population were of the view that shifts and gaps occur in manual screen printing. 10 respondents representing 9.26 % of the sample population mentioned blurred edges as one of the defects that occur in manual screen printing.

Table 9: some defects associated with Manual Screen Printing

Responses	Frequency	Percentage (%)
Bleeding of designs	28	25.93
Blurred edges	10	9.26
Overlapping of designs	31	28.70
Shifts and gaps in designs	15	13.89
Drying of screen due to slow printing process	24	22.22
Total	**108**	**100**

Source: Field Data, June 2017

4.20 Addressing the defects of Manual Screen printing
Table 10 below presents the responses of respondents on how to address the defects of Manual Screen printing. 46 respondents representing 42.59% of the sample population stated that in order to address the defects of Manual Screen printing, an automated device should be manufactured. Furthermore, 23 respondents representing 21.29% of the sample population intimated that enough and even pressure should be exerted on the screen during printing to prevent bleeding and patchy printing. Additionally, a good number of respondents (19) representing 17.59% of the sample opined that good screen development would avert the defects of manual screen printing while 13 respondents representing 12.04% of the sample population stated that when the appropriate tools and materials are used, the defects of Manual Screen printing will be avoided. Last but not the least, 7 respondents representing 6.49 of the sample population were of the view that more hands should be engaged during screen printing.

Table 10: addressing the defects of Manual Screen Printing

Responses	Frequency	Percentage (%)
Manufacture of an automated device	46	42.59
Good development of screens	19	17.59
Limiting pressure exerted on screen during printing	23	21.29
Using the appropriate tools and materials	13	12.04
Employing more hands during printing	7	6.49
Total	**108**	**100**

Source: Field Data, June 2017

4. 2 Production Processes
In order to address the problems associated with t-shirt printing using the traditional approach, the researchers designed and manufactured the "Portable T-shirt Printing Machine." The machine which was made from metal pipes and metal plates has the following features: an adjustable squeegee, leather padded table, an adjustable metallic frame which holds the screen during printing and a magnetic holder which holds the frame taut during printing without the help of a second person. The squeegee can be moved manually by the help of a bearing and a hollow pipe. The squeegee blade which is made of rubber can easily be removed and washed after each

printing session. The "Portable T-shirt Printing Machine" which is 75cm long, 45cm wide and 12cm high can be carried easily and printing can be done anywhere, whether there is electricity or not. The adjustable metallic frame which holds the frame can be adjusted to suit any screen size; ranging from (40 cm by 40cm) to (15cm by 15m) or even smaller screens. The printing is less stressful as there is no need to set up a fresh printing table and additional hands are not needed.

4.21 Tools and Materials
The following tools and materials were used to produce the machine: welding machine, file, grinding machine, electrode, hacksaw, tape measure, vice, g-clamp, pencil and eraser, angle pipes, hollow pipes, bolts and nuts, galvanise metal plate, foam, leather, plywood, hinges, magnetic locker, iron rod, two holders, rubber blade, auto-base paint, lacquer, spraying machine, porti filler and hardener and sand paper.

4.22 Production
i) After developing various ideas from existing machines, the production processes started. First, the base frame was formed using the hollow pipes. The pipes were cut to the required dimensions by the help of a hacksaw and then welded using the welding machine. Plate 2 below describes that activity:
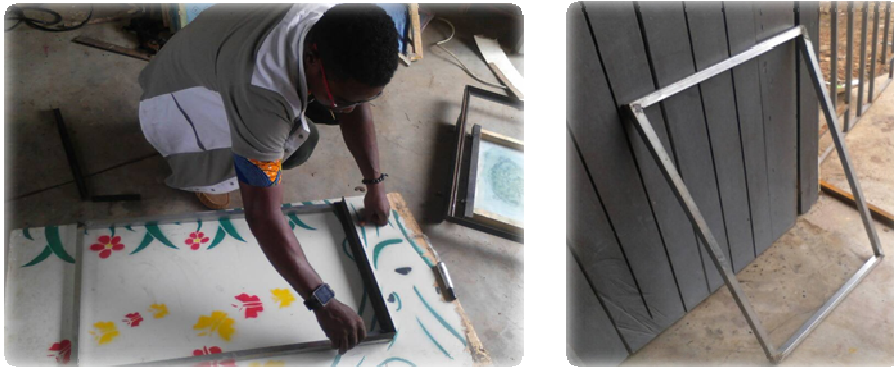

Plate 2: welding of the base frame

ii) Secondly, the angle pipes were welded to the base frame to serve as a rail through which the squeegee will move by the help of a bearing.

Plate: 3 attachment of square pipes to the base frame

iii) This was followed by welding the frame holders to the top frame as illustrated below. The frame holders are made up of two angle bars and adjusters. The adjusters which are made up of bolts and nuts make it possible for the holders to be adjusted to suite the required frame size (between 4ocm and 15cm).

Plate 4: attachment of frame holders to the top frame

iv) At this stage of the construction process, the top frame and base frame were joined together using hinges as shown below. This enables the two frames to open and close when the need arises. A pair of small shock bars was later attached to both the top and base frames to enable the top frame stand still when it is opened for fixing of the screen. The shock bars also play an important role in preventing any accidents that may occur as a result of the top frame falling off.
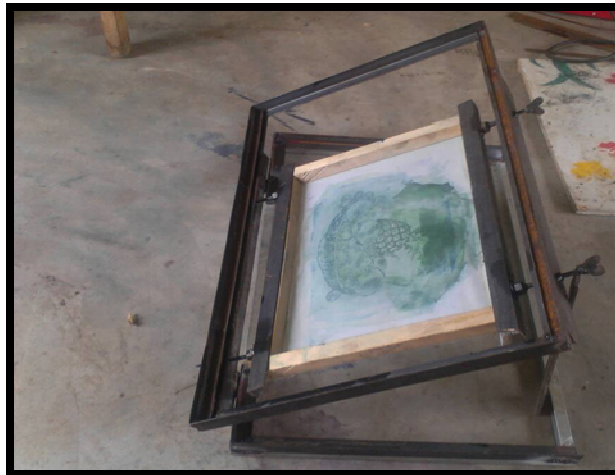

Plate5: connection of the base and top frames

v) This was followed by fixing the squeegee frame into the rail in readiness for fixing the squeegee. Two bearings were fixed to the sides of the squeegee frame to facilitate the movement of the squeegee when it is propelled. The squeegee frame is made up of two flat metal plates connected with an angle pipe and iron rod at the middle section. The iron rod has been fixed there purposely to give stability to the squeegee frame.

Plate 6: fixing of squeegee frame

vi) The next stage was to fix the squeegee in the squeegee frame as shown in plate 7 below. The squeegee is made up of a metallic handle and a rubber blade. The rubber blade can be easily removed and cleaned after each printing session. The squeegee handle can accommodate wider or smaller blades depending on the size of the screen being used. The squeegee can be detached from the squeegee frame for replacement during printing or for maintenance.

Plate 7: fixing of the squeegee

4.23 Finishing
Finally, the machine was given a finishing treatment by first grinding the welded parts to smoothen them. Porti filler was then applied at rough edges and welded parts and then polished by sand-papering. This was followed by priming of the metal surfaces with grey paint. After that, blue auto-base paint was sprayed evenly to cover all metal parts except the handle of the squeegee which was sprayed with gray colour. After the paint had dried, a thin film of lacquer was then applied to enhance the beauty and sheen of the machine. In addition, two frame handles were fixed to the top frame to make lifting easy. Two magnetic lockers were also fixed to the base frame to ensure the firm contact of the screen with the printing table without any human assistance. The leather padded printing table was finally, fixed into the base frame as illustrated in plate 8 below. The padded table can be easily detached from the machine for cleaning or easy transport of the machine from one place to another.

Plate 8: fixing of the padded printing table into the machine

Plate 9: finished work.

4.24 Mode of Operation

The Portable T-shirt Printing Machine can be used anywhere, whether there is electricity or not. Users will not have to go through the trouble of preparing a fresh printing table because the machine comes with an already prepared printing table which is well padded with foam and leather. The machine is suitable for printing t-shirts, handkerchiefs, scarf and small table cloths. To print with this machine, first lift the top frame and fix the screen in its holder. The screen holder which is adjustable can take screens from 40cm to 15cm. After fixing the screen, fold and put the t-shirt onto the printing table and then fix the screen onto it by dropping the top frame. Ensure that the magnetic locker holds the screen tight to achieve a smooth printing. After that, pour the printing paste into the reservoir of the screen and then turn on the adjusters attached to the squeegee handle to drop the squeegee for printing to commence. Having done that, pull the squeegee gently but firmly for printing to occur. You can now lift the top frame and remove the t-shirt for drying.

Plate 10: lifting of the top frame for printing to start

4.25 Testing of Machine

After production, the machine was tested by printing one colour on a t-shirt. It was observed that the design came out well and was devoid of any "bleedings". The squeegee was also able to move with ease and printing was done once as compared to the traditional printing where the squeegee is moved several times before a design is printed. Quite apart from these, it was observed that the magnetic locker was able to hold the screen firmly on the t-shirt and this made it possible for only one person to do the printing. This will invariably contribute to the cut down on production cost. However, it is believed that when the machine is automated, the speed will increase and that will contribute to a higher production rate and more income.

Plate 11: result after testing machine

5.0 SUMMARY OF FINDINGS, CONCLUSION AND RECOMMENDATIONS

5.1 FINDINGS

The following main findings of the study have been itemised:

➢ The speed of Manual Screen printing can be enhanced by developing a machine.

➢ The Traditional Screen printing technique is bedevilled with challenges.

➢ T-shirts are important in the social life of a people.

➢ There is a high demand for t-shirts in Ghana.

➢ The fastness and efficiency of the t-shirt printing process have a direct relation with the income earned.

➢ The Portable T-Shirt printing machine prints with fewer errors.

➢ The machine has relatively high speed as compared to Traditional Screen printing.

➢ The Portable T-shirt printing machine can be printed by only one person without any assistance.

5.2 CONCLUSION

Interesting designs are printed on t-shirts and other fabric surfaces to decorate and enhance their beauty. In the textile industry, complex printing machinery are used to print intricate designs for customer appeal. They include: engraved copper roller printing machines, rotary screen printing machines, automated flat screen printing

machines and the like. These machines have the capacity to print several yards of fabric a day because of their high speed. Their printing quality is also very good. However, in the Hand Screen printing industry in Ghana, crude methods of printing are employed. Some local printers improvise plywood and bathroom slippers as squeegee for printing. As a result, poor quality designs are produced which attract only few customers and this affects the revenue that is generated from the sale of such works. With the introduction of the "Portable T-shirt Printing Machine," it is hoped that the speed and quality of printing will be enhanced greatly.

5.3 RECOMMENDATIONS
The following recommendations have given based on the findings. It is hoped that the recommendations will be implemented to the latter.
- The machine must be maintained regularly.
- The printing table and squeegee must be removed and cleaned with soap and water after each printing session.
- The machine must be oiled regularly to prevent friction and corrosion of the metal parts.
- Future researchers should use a step-up motor to automate the printing mechanism so as to increase the speed of printing.
- The local printers must adopt the "Portable T-shirt Printing Machine" to ameliorate their printing process.

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