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***Abstract*— It is increasingly important for Science and Engineering educators and students to be aware that, solving complex problems require methodologies like Design Thinking. It is also important to bring this knowledge into industry settings as there is no evidence this exist for most industries in Nigeria. A workshop was conducted, following the Design Thinking approach, to help educators, students, and industrial partners to collaboratively generate ideas towards the development of a web-based virtual laboratory. In doing so, participants gain a hands-on experience of how this method is used to develop products and services. This paper reports on how the workshop was implemented, evaluated, the observations made, and lessons learned. The research was carried out with the hypothesis that the design thinking workshop improves the quality of understanding of design thinking of the participants. In the end, findings of the pretest and post-test scores of the participants shows significant (30%) increased knowledge gained by participants.**

Keywords— Design thinking, Software Engineering, Virtual Laboratory, Industry, Design Thinking Workshop.

I. INTRODUCTION

Design thinking is a problem-solving methodology that employs the use of creative and user-centric approach towards the designing and creation of products. It is an iterative and nonlinear process consisting of five phases. See Fig. 1. It involves interaction between business or organisation and users, enquiring feedbacks from users to understand their needs and coming up with effective solutions to meet those needs.

Design thinking is defined by [1] as "a way of finding human needs and creating new solutions using the tools and mindsets of design practitioners". It has become one of the most important skills that has brought innovation to organizations in the twenty-first century. Today, design thinking is continuously being enlarged and its meaning redefined by a growing number of companies, universities, and consulting firms [2].

The principles of design thinking conflicts with many traditional methods of software development in information technology. Most of the methods for developing information systems end up with abstract models. And many decision makers don't understand such models. Design Thinking uses a different approach that enables fast and easy building of prototypes and testing of new ideas [2]. Building prototypes that can be experienced is one of the central principle of design thinking. In the innovation process, building prototypes is very important aspect, and design thinking has that as a core principle.

Another principle of design thinking is that it requires a special place. To successfully conduct design thinking projects, these special spaces are designed to be well equipped with the right materials needing to meet the need of the teams [2]. As rightly identified by [3], "Design thinking has its origins in the training and the professional practice of designers, but these are principles that can be practiced by everyone and extended to every field of activity".

The collaboration of design teams and various stakeholders of a company often leads to breakthroughs for resolving their problems. It is when collaborations like that happens that they are often able to win the commitments of members from multiple divisions of the organisation to see new ideas through to production. As [4] examined, design thinking is not the only successful method for generating collaboration: so is Straus, Charrettes, and the Appreciative Inquiry Method. However, it has gained more prominence in the last decade, and is a potential candidate in negotiating the industry-academia engagement in product development.

Research has suggested that the use of design thinking approach can have a significant impact on software development as it facilitates a deep understanding of user needs and increase collaboration [3,4]. According to [5], design thinking is a concept that promises increase in innovativeness through a more user-centred approach to innovation [5]. As it produces positive outcome in settings which are characterized by incomplete, contradictory, ambiguous, and changing requirements [6]. There is however, no evidence of this type of training in the curriculum of Nigerian University education. In addition, there is no evidence this is employed by industrial partners for development of products in Nigeria.

To this end, considering the foregone mentioned benefits of employing design thinking for new products, a workshop was conducted involving students and faculty members of two HEIs and their industrial partners in a funded project named Virtual Laboratory (VLab) for Science and Engineering students supported by the Royal Academy of Engineering (RAEng), London, UK. V-Lab is an online platform that was designed using design thinking through the workshop. VLab aim to support practical science and engineering courses towards equal access to knowledge and quality skills.

This paper presents the process involved in the design thinking workshop organised to enlighten various stakeholders from educational and industrial sectors on the concepts behind design thinking methodology and engaging them in applying these concepts into the development of virtual laboratory for science and engineering (VLab). The paper also highlights preliminary evaluation of the knowledge acquired from the workshop.

The paper is organized into sections. Section I is the background to the study, section II provides related literatures, section III gives information about the methodology used, section IV presents the findings, section V discusses these findings while sections VI provides the conclusion.

II. RELATED WORKS

In recent times, designers are asked by organizations to produce ideas that better meet users' desires and needs rather than improve already developed idea to make it appealing to the users [5].

Over the past decades, research based on design thinking has evolved. In tracing the origin of design thinking, from over three decades of research, [7] proposes three characteristics of design thinking that emerges. Table 1 shows important literature of characterization from each decade. The first on the table is the cognitive style as it is related to design thinking, which focus on individual designer. The main objective is to explore how design experts make decisions and cognitive research is particularly of interest in the role of the designer himself.

Time	Theory	Role	References
1980s	Cognitive Style	DT as the way designers think	Cross, 1982 [21], Schön,1983 [22], Rowe, 1987 [23]
1990s	General Theory of Design	DT as a link between departments	Buchanan, 1992 [24] Simon, 1996 [25]
2000s	Organizational Resource	DT as product development leader	Micheli, 2012 [26] Liedtka, 2015 [27]

Table 1: Design thinking across 3 decades

The second theory of design thinking is the general theory of design. Researchers adopting this view claimed that the concept of design thinking has changed from aesthetic modelling to wicked problem solving, having a proposed notion that all professionals should be able to take part in design ([8], [9]). Since the early 21st century, the discourse of design thinking as an organizational resource has gained great significance in the field of design and management, which is further discussed in this paper.

Within this theoretical lens, [10] suggests that collaboration increases among professionals who are better equipped with design thinking skills to carryout design thinking process, leading to product differentiation and consequently, attributes to firms' competitiveness.

Design thinking (DT) generally involves several stakeholders participating in the process, to offers ideas and rapid test these ideas. It supports iterative idea generation, constant review and report on performance, thus enabling development team of products review their decisions according to the goals.

Design thinking have in recent time been employed by the software industry in advanced countries, this cannot be said of software industries in the global south especially in Nigeria. However, it is considered an effective tool to engage various stakeholders, such as software engineers being able to address the needs of user's [11]. From a more general point of view, [12] have found that adding design thinking into the product development process can result in significantly reduce cost of production as design thinking shorten time to development and redesign of work.

Researchers have been looking for ways to facilitate the integration of design thinking to software development so as to integrate more diverse knowledge to handle challenges faced during the development processes. According to [13], there are four ways design thinking can support software development.

- The split project Model: employing design thinking as separate project before software development.
- Overlapping teams' model: design thinking as the initial process phase with the participation of one or more development team members.
- Unified project model: design thinking as the initial process phase and A large overlap of development team and design thinking team.
- Toolbox model: the methods developers can use to solve problems they cannot solve using IT methods.

Several authors have proposed for the integration of design

thinking (DT) into (agile) software development models. There are similarities found between agile application development methodologies and design thinking [14].

The core features of both approaches are 'user centricity', 'extensive team communication', and 'iterative learning and development processes' ([14], [15]). [14] proposed a framework for integrating a core process of DT and agile concepts in the area of the digital transformation. [16] depicts the possible effects of DT in agile user experience. There are previous research made that has addressed the aspects of user-centered design approaches in agile software development ([17], [18], [19], [20]). The research on agile and DT on software engineering is however limited.

III. METHODOLOGY

A. Objective

The main objective of this research is to study the impact of the design thinking workshop on the participants. To identify if the workshop improved their knowledge and understanding of design thinking as well as how satisfied they are with the program. The evaluation in this study was made with the data collected from the pre-test and post-tests conducted during the program.

B. Hypothesis

This research study is based on a positive hypothesis that the design thinking workshop, improves the quality understanding of design thinking of the participants of the workshop.

C. Workshop implementation

The design thinking workshop consist of two sessions. In the first session, the participants were introduced to design thinking and case study on and how design thinking was applied to find effective solutions [28]. In the second session, the participants where further enlightened on the phases of design thinking process. Participants were then grouped into 5 groups and engaged in sequential brainstorming activities (Fig. 2 and Fig. 3) along the design thinking phases, to enable them to come up with designs and agree on the design of V-Lab and virtual experiments that will lead to user-friendly learning environment for the V-Lab platform. A pre-test and post-test were also administered to the participants, before and after the workshop respectively. Table 2 shows the step-by-step activities involved in the workshop.

WORKSHOP ACTIVITIES
FIRST SESSION: INTRODUCTION TO DESIGN THINKING
Pre-Test Questionnaire administration
Introduction to Design thinking
Case Study: Designing Technology for Marginalised Namibians
WORKSHOP ACTIVITIES
SECOND SESSION: DESIGN THINKING PROPER
Group formation
Empathy: Role-playing
Defining the Problem
Ideating
Prototyping
Brainstorming activity
Post-Test Questionnaire administration

Table 2: Workshop Activities

D. Research design

The study uses both qualitative and quantitative methods to collect and analyse respondents' data. A pre-test and post-test were administered to participants to determine the change in their level of understanding of design thinking acquired during the workshop.

The same questionnaire was assigned to the participants both at the start and end of the program. The questionnaire contains questions which the participants were required to fill, state whether they agreed or disagreed (True or False) to given statements, while others were multiple-choice questions. The following are some of the questions listed below.

Questions
What is a design thinking?
What are the components/process of design thinking?
What are your expectations of this workshop? What do you hope to gain by participating in it?
What is empathy in design thinking?
Design thinking significantly reduces time to market launch. *True or False*
Design thinking is for only Engineers and Scientists. *True or False*
The Define stage implies stating the problem on a piece of a paper. *True or False*
Design thinking started as an engineering concept. *True or False*
Which aspect of design thinking process involves generating big ideas from brainstorming a) Empathy b) Analyse c) Prototype d) Ideation

Table 3: Pre-test and Post-Test Questions

Fig. 1: Five phases of Design Thinking

Fig. 2: Brainstorming activities among group members

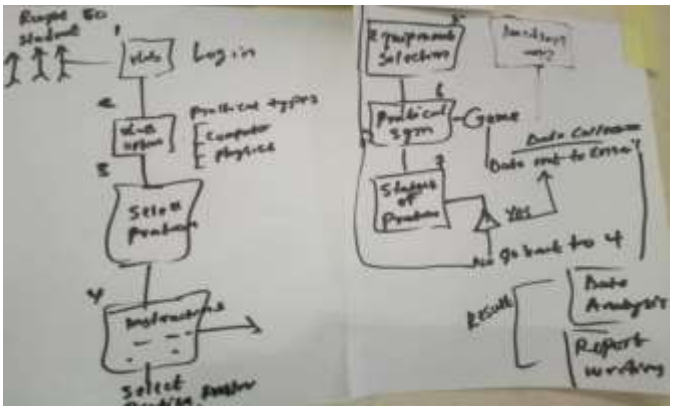

Fig. 3: prototype of design developed during brainstorming

E. Sample

A total number of 35 participants took part in the Design Thinking workshop. The participants were drawn from faculties, students, and industrial partners of the Virtual Laboratory (VLab) project. The pre-test and post-test questionnaires assigned to participants were printed to ease the data collection.

IV. FINDINGS

The data retrieved from the pre-test and post-test was analysed. By taking the objective and hypothesis into consideration, the research team aim to measure the difference between the pre-test and post-test scores of the participants. To achieve this,the team performed a t-test on pre-test and post-test data obtained. T-test is a statistical method used to determine whether there exist a significant difference between two groups of data [29]. The chart in Fig. 4 shows the result of our findings.

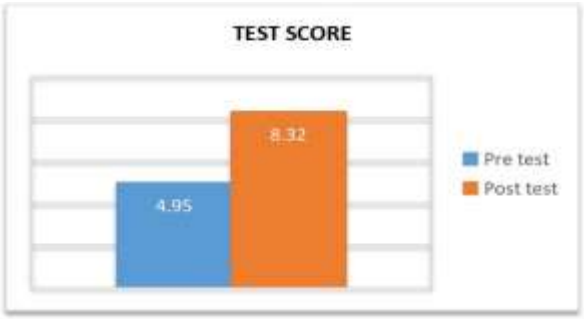

Fig. 4:Average score of pre-test and post-test

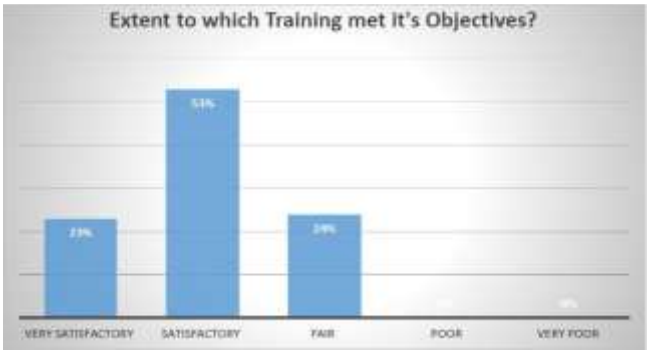

Fig. 5: Percentage of Respondents who believe the training objectives were met

The pre-test and post-tests of the 135 participants across various stakeholders revealed a very significant increment in participant understanding of design thinking.
The difference between the score of the pre-test and post-test is significant (P = 0.0001 at 95%). The pre-test having an average score of 4.95 (45%) whereas that of the post-test is 8.32 (75.63%). This show an increase in the average score of 3.37 (30.63%).

Fig. 6: Percentage of Respondents whose expectations of workshoop was met

A. Thematic analyses

At the end of the post-test questionnaire, the participants were given the opportunity to comment and make recommendations they may have above the workshop. The data received from open comments and open-ended questions were analyzed with the help of thematic analysis. Thematic analysis is a method used for identifying, analysing, and reporting observed patterns (known as themes) found within the data [30]. The procedure of the analyses was adapted from [30].

A qualitative approach was employed to the participants' comments to derive various themes.

1) Satisfactory: More than 70% of the participants expressed their satisfaction with the workshop and how pleased they were with the event. See Fig. 6.

2) Objective met: Most respondents (86%) also stated that the objective of the workshop was met. See Fig. 5.

3) Communication: The respondents also noted they experienced a good communication between them and the facilitators. Although there were few responses from thosewho expressed dissatisfaction in the aspect of communication.

4) Improvement: There were requests made by few respondents on the quality of the workshop. For example, a respondent highlighted the need for better logistical arrangements, like the use of multiple halls to avoid interference between brainstorming groups.

V. DISCUSSION

Most participants scored better in the post-test (8.32/10) than they did in the pre-test (4.95/10), an increase of 30%. This proves the hypothesis to be correct that design thinking workshop could also enhance the knowledge of participants in the concept of design thinking.

VI. CONCLUSION

This paper presented the experiences in undertaking a workshop on design thinking towards improving the knowledge of design thinking. The study aims to measure the impact of the design thinking workshop on the participants. The team conclude that the workshop improved participants' understanding of design thinking. The study shows participant significant increase (30%) in DT knowledge and understanding.

VII. ACKNOWLEDGEMENT

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