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# Contextual use of IoT based water quality control system

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**Abstract.** ‘Solutions’ are often deployed as interventions without lasting benefit to communities and stakeholders. In the case of water, a basic need and necessity for living and a part of goal 6 of the sustainable development goal, poor water monitoring systems have been one of the reasons for water wastage around communities. The inadequate control of water in and out of the storage has been a part of the cause of water wastage. In Anchor University Lagos, there has been a constant wastage of water. The extents of water in the tanks are likewise not ascertained for proactive measures for enough provision. This is besides the fact that the quality status of the water cannot be asserted before consumption by students. The above-identified issues have therefore become the motivation for this research project. In this paper, considering the ineffectiveness of the current quality control system in Anchor University Lagos, an IoT-based water quantity control- and quality assurance system was implemented following a build, process, and experimental methodology. The system alerts on the possibility of water shortage and the safety of water for consumption. Different sensory modules were connected to raspberry pi 3 devices, a micro-controller, to enable the IoT-based system to function properly. Informed by UTAUT, data was retrieved and analyzed from the sensors through the micro-controller and displayed onto an android based application for end-users. A users’ acceptance survey was carried out, influenced by UTAUT, to ascertain the performance and effort expectancy analysis of the system alongside the contextual social influence and the facilitating conditions. We observed a favourable disposition of end-users in welcoming and engaging. More significantly, the belief the users have to expectancy regarding leveraging the system for water quantity and the degree of impact that influencer will have. Further contextual studies shall incorporate the daily consumption rate of water volume to capacity management.

**Keywords:** Water, Quality, Internet-of-Things, Raspberry pi-3, Sensor, Android, SDG, Acceptance, UTAUT.

## 1 Introduction

Water is not only a basic, essential need of humankind, it is a necessity for living. Water must be available to meet the 20 to 50 liters consumption by human daily and must be kept clean. With COVID-19, the importance of water came to fore even more for many. The United Nations recognized the criticality of water and noting majority are without access, stressed the important of improved water quality in places where water is provided. See Goal 6 of the Sustainable Development Goals – SDG – ([www.un.org/sustainabledevelopment/water-and-sanitation/](http://www.un.org/sustainabledevelopment/water-and-sanitation/)). There is a need for water to be measured and regulated to avoid avoid wastage and inadequacy. More so, Pasika and Gandla [1] advocate real-time monitoring. This calls for developing solutions that can regulate the flow and monitoring of a water system; a gap that the Internet of Things (IoT) is capable of filling.

The IoT refers to a whole lot of global physical devices that are connected to the internet with data collection and sharing capabilities [2]. This is aided by the proliferation of affordable computer chips and the universality of wireless networks which is leveraged in small objects as pill to something as big as an airplane. The connectivity of the different devices or objects with sensors adds a level of digital intelligence to hitherto dumb devices, enabling them to communicate real-time data without the intervention of human beings. The IoT is making the fabric of the world around us smarter and more responsive, merging the digital and physical universes [3], just as Cloud computing likewise advances the possibility of remote functionality in a digitalized everyday capability [4]. The IoT is a relatively new pattern in information and communication technology (ICT) as it is widely described as the network of objects [5] (things) which is embedded with sensor modules and other technologies for the purpose of connecting and exchanging data with other devices and systems abroad [6]. Hence, IoT has wide deployment and utilitarian value across use cases [7] including everyday tasks and way of life [8]. While the deployment of IoT is widespread for industrial innovative disruptions [9], domestic activities that daily touches the life of ordinary citizens could likewise be enhanced by the instrumentality of the Internet of Things [10]. For instance, supposed inconsequential monitoring of water systems in domestic domains could mar water provision intentions if proactive measures are not put in place for effective management [11] as well as the need to ensure quality water for consumption and other domestic use [12]. Hence, monitoring water provisional systems would help crop the incessant wastage of water in communities of developing countries like Nigeria and as well ensure mitigating factors against low quality water for public consumption. In the university community of Anchor University for instance, issues associated with wastages and inadequate water provision is what the water management team struggle with on a daily basis. Consequent upon the foregoing, automation of water monitoring and management systems, away from the traditional physical inspection, in no small ways enhances water provisioning efficiency. In this study, the build, process, and experimental research methodology is adopted towards automating the water monitoring and management system at the Anchor University Lagos. This research project investigates an IoT-based water control system that keep track of the water level in real-time. The water quality system compares values received from the sensors with some preset

water level parameters to accurately ascertain, in real time, the current level of water in various reservoirs through an Android-based technology. The Unified Theory of Acceptance and Use of Technology – UTAUT [13] approach was used for the evaluation of the automated system in this study.

The rest of the study is structured thus: session II discusses related studies and session III unveils the proposed methodology. Session IV discusses the result and session V concludes this study with recommendations.

## 2 Related studies

The concept of connecting sensors and some level of intelligence to basic objects is a continuous germane discussion [14] apart from some early projects, including an internet-connected vending machine, there is still a growing demand for smart objects. Some of the militating factors were the size of chips with their bulky nature hence no way for objects to communicate effectively until now. The adoption of Radio Frequency Identification (RFID) tags, low-power chips that can communicate wirelessly, solved some of this issue [15], along with the increasing availability of broadband internet and cellular and wireless networking.

The adoption of IPv6, which, among other things, should provide enough IP addresses for every device in the world (or indeed this galaxy) is ever likely to be needed, was also a necessary step for the IoT to scale [16]. IoT has been widely adopted for health services [17] where wearables or sensors are connected to patients in enabling the monitoring of patient's condition remotely in real time. The agriculture use case of IoT is likewise widespread [18] in the area of smart farms in both developing and developed societies. Specifically, the quality of soil etc. is sometimes ascertained through the instrumentality of IoT. Smart homes and smart grid are other areas of applications for real estate [19] and energy industry [20] use cases. More so, water quality monitoring is facilitated by IoT acting as sensors for smart systems [1]. In water quantity control, IoT could be deployed through the instrumentality of an ultrasonic sensor to determine the level of water which can be monitored from the comfort of a mobile phone connected to the internet and the automation system. Indeed, IoTs are burgeoning with their use for secure, smart environment looking promising [21].

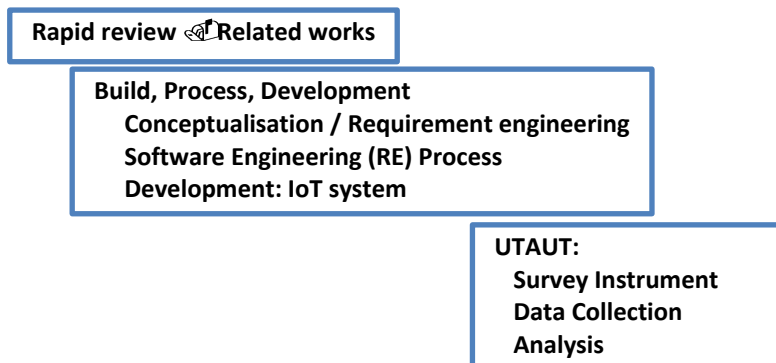
Water quality monitoring systems detects water level, amount of water released from the tank, and object detection. The values from the sensors can be obtained from micro devices like Arduino UNO Raspberry Pi and engaged using a Wi-Fi system. Saravanan et al. [22], implemented an Intelligent IoT-based Water Quality Monitoring system, where a PH sensor and TDS meter were deployed for collecting water parameters periodically from different types of water. Collected water parameters are sent to the microcontroller and are sent through serial communication to Raspberry Pi3. The Pi3 processor got the K-Means clustering algorithm in grouping the water parameters into different clusters based on PH and TDS and accordingly trained the data set for predicting the quality of water as good or bad. This information is updated on a cloud-based webpage to aid informed decision of water authorities.

Users can surf web page of a system using a local web browser and can control the industrial devices (micro board), as well as their status from a remote place. The work of [23] proposes an IoT-based cost-effective system that monitors the quality of water in real-time. The design and implementation of the system is done with WeMos D1 mini and sensors (pH, turbidity, temperature, and ultrasonic). The experiment setup was developed and tested for water quality data acquisition, online data transfer, monitoring, recording, and analysis. It is experimentally observed that the system takes less than a minute to update its values, which is an optimal timeframe for residents. Sensor-based water quality monitoring system utilizing microcontrollers leverages Wireless Sensor Network (WSN), a communication system for inter and intra-node communication across several sensors [24]. Access to real-time data is achievable by remote monitoring of IoTs in-situ data collection, aggregation, processing and displaying within an information system. Yasin et al. [25, p. 56] in their review note that such smart water management systems are designed to collect meaningful and actionable data on water supply, pressure, and delivery. Most of the related works present the ‘technical’ working of their solutions. Pasika and Gandla [1] included the algorithms, while Overmars and Venkatraman [21] presented their process flow diagram for their case study. This paper takes these approaches further by highlighting part of the software engineering use-case and users’ ‘view’ of our implemented IoT-based water quality system for our Anchor University’s case study.

### 3 Research methodology

The question then is how we leverage IoT and micro-boards in deploying water monitoring system based on sound software engineering principles, such as the context of a university environment in a fast-growing mega city (in a third world).

#### 3.1 Research approach



**Fig. 1.** Overview of the research approach of the IoT-based water quality system.

The approach as depicted in Fig. 1 started off with the rapid literature review of related work as presented in the last section. In this section, we shall look at the build, process, and development which is informed by software engineering principles. The UTAUT informed experimental trial is discussed in the next section (results and discussion).

The Build, Process and Experimental research approach is adopted in this study. The building methodology of the study consist of an IoT system involving the main controller, sensor module, GPIO pins, memory card (storage device). The process methodology of this study is in the areas of Software Engineering and Man-Machine Interface which deals with the way humans build and use computer systems. The experimental methodology used in this study is a 5 scale, UTAUT framework.

### 3.2 Research design.

The IoT-based system uses a raspberry pi as the main controller with different sensors connected to it and an android based application for end users. Data comes from sensors connected to the raspberry pi controller, which was retrieved by a Python script. The collected data were compared with the World Health Organization (WHO) standards for drinking water. An analysis of the data ensues and is displayed on the mobile application with certain predictions based on the earlier mentioned comparison. The layered architectural framework for the study is as captured in Fig. 2a with the application framework captured in Fig. 2b.

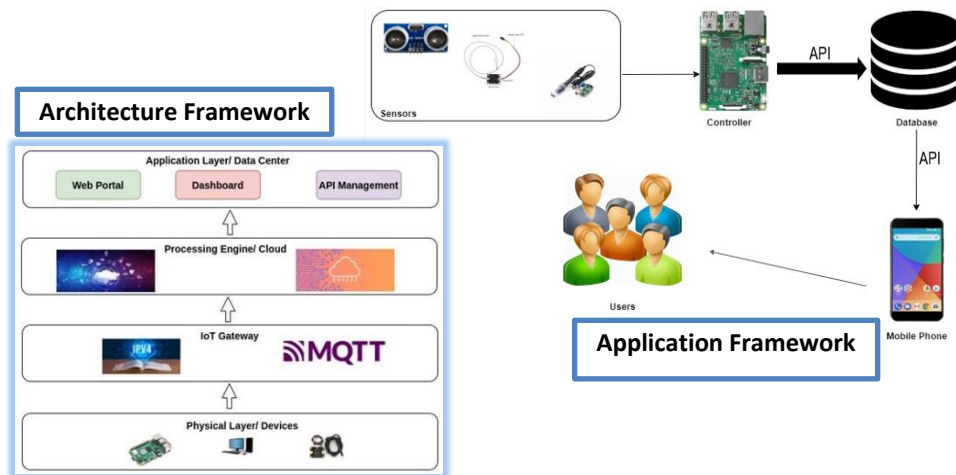
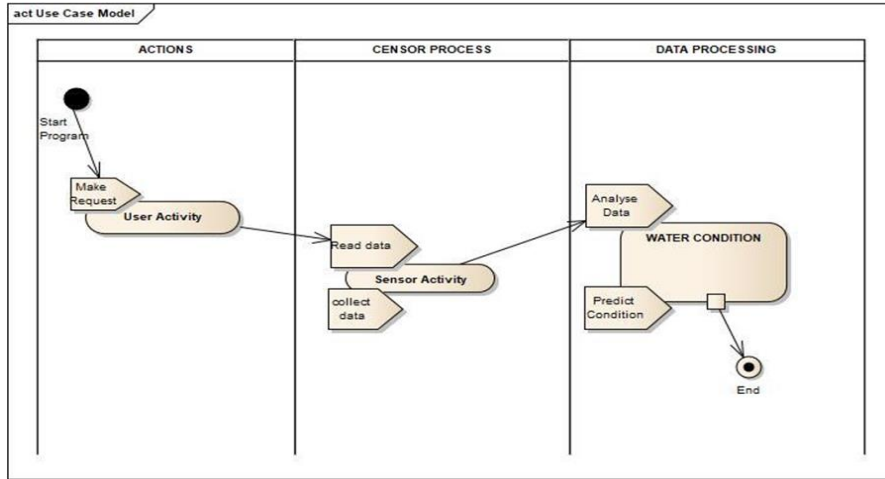
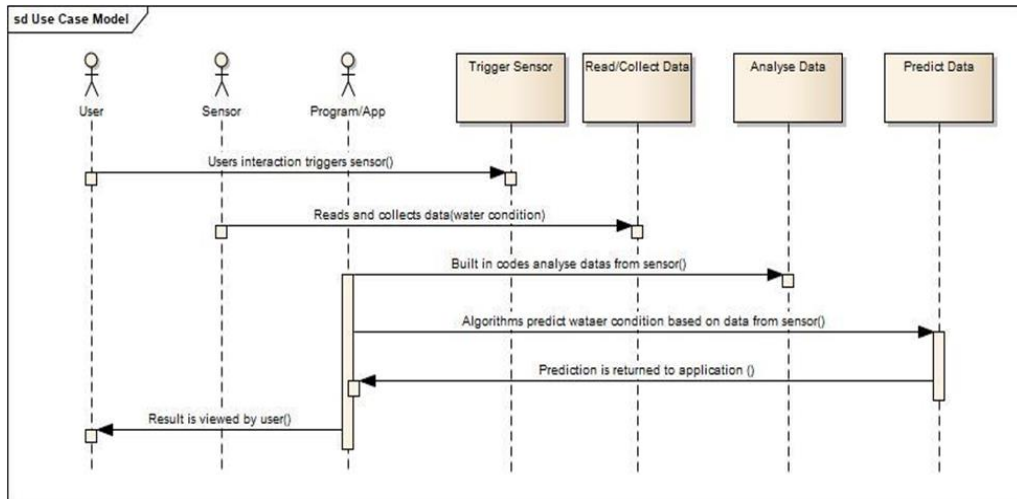


Fig. 2. Architectural (1a) and application framework (1b) of the water quality system.



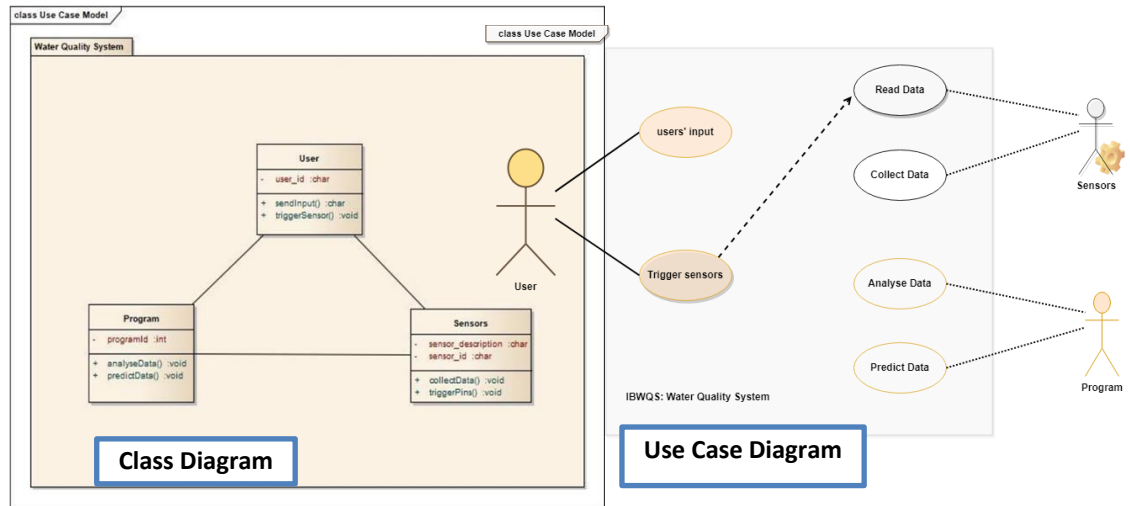
**Fig. 3.** Activity diagram of the water quality system.

The flow of sequential activities and actions for the functionality of the framework is as captured in an activity diagram depicted in Fig. 3, while the series of messages and interactions between actors and objects are as described in the sequence diagram of Fig. 4 where communications are represented in an orderly manner. The classes of the proposed framework alongside their attributes and consequential behaviors are as described in Fig. 5a while the analysis of the system's functional and non-functional requirements, as expressed by different end users is as captured on the UML use case diagram in Fig. 5b, indicating the actors and their relationships within the design framework.



**Fig. 4.** Use case activity sequence diagram of the water quality system.





**Fig. 5.** The class diagram (5a) and use case diagram (5b) of the water quality system.

Requirement gathering (the requirement engineering) based on the architectural and application framework, and the use case activity sequence was done as summarized in Table 1.

**Table 1.** Listing of the hardware and software requirement.

S/N	Hardware	Function	Remarks
1.	GPIO pins	GPIO pins are cables deployed for data and power transmissions, and the overall communication between the raspberry pi microcontroller and the sensors.	
2.	Resistors	Resistors interfaces the ultrasonic sensor which needed only 3.3 volts.	The raspberry pi delivers 5 volt or 3 volts, therefore the resistors used were to step down the 5volts to 3.3 volts.
3.	GPIO Ex-tender	Used to extend the communication pins of the micro-controller	
4.	Bread board		
5.	Memory card	Main storage for the microcontroller.	System database
6.	Raspberry pi 3b+	a microcontroller	
7.	Ph Sensor Module		
8.	TDS sensor module		

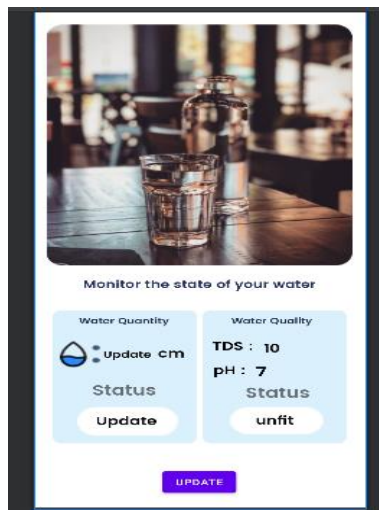
S/N	Hardware	Function	Remarks
9.	Ultrasonic Level sensor		
10.	Raspbian software		
11.	Python coding	Used to build the scripts that communicates with the raspberry pi 3. These files include, firebase.py, distance.py.	A scheduler called crontab was used to run the firebase.py script every minute
12.	Java coding	Used in android studio to develop the application that will intelligently determine the quantity of water in a tank. Java is also used in to develop the User Interface of the application for the users of the system.	Certain water levels were stored in different array list. Then, the distance retrieved from the database is then check in the list to see if it is present, if present, the condition is true else it checks for the next condition.

## 4 Result and discussion

We shall now discuss the interesting findings from our field experience.

### 4.1 Water monitoring app

The interface to the water monitoring system is for Anchor University Lagos is an Android-based app, shown in Fig. 6.



**Fig. 6.** (Android-based) user interface of the monitor quality state.

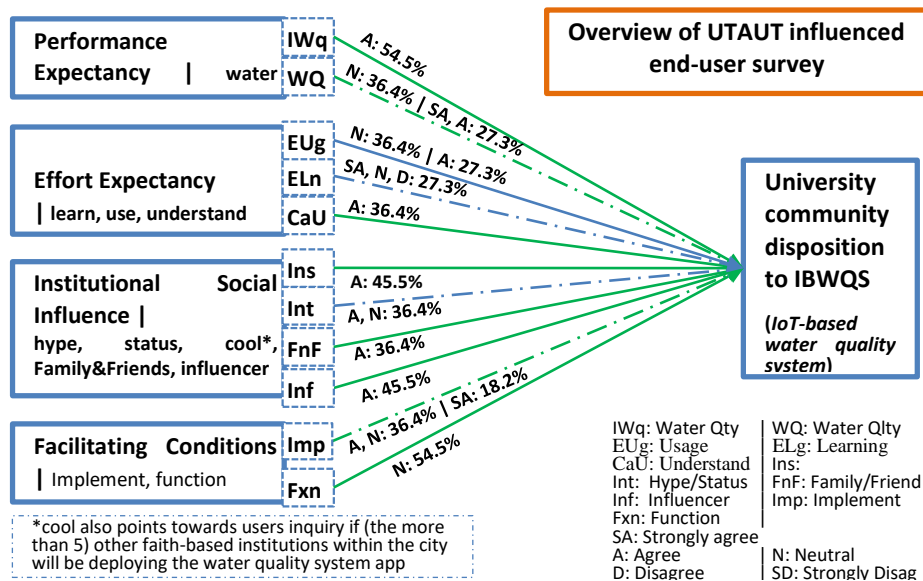
Two segments of water quantity and quality status were captured on the device which is easily updated to reflect current status of the water reticulation system. The

water quantity is measured in *cm* on the device while the quality segment shows the TDS and pH value of the water. Status label of the water quality segment shows the usability status of the water as *unfit* or *fit* for use. The device was deployed for experimentation by end users to evaluate its performance, questionnaires were administered on end users to evaluate their perception of the new water management control system.

## 4.2 UTAUT evaluation

As with other researchers trying to gain insight into the adoption of new innovation, we leverage the UTAUT framework. The UTAUT construct for the water monitoring system was designed to gauge performance (users usage perspective), institutional (social) influence, and the facilitating conditions. We acknowledge and take note of Dwivedi et al. [13, p. 719] call for researchers to go beyond behavioural intention and usage behaviour, to give thought to the contextual relationships that may be potentially important. The test bed is a relatively new university with its own dynamics and reality, yet it exists within another interfacing reality – a mega city.

The UTAUT construct for the water monitoring system was designed to gauge performance and effort (users usage perspective), institutional (social) influence, and the facilitating conditions. The construct design is as depicted in **Fig. 7**, which currently shows the Likert scoring in this phase of the research project.



**Fig. 7.** Summary findings with Likert scoring.

In the current iteration, trust, and cost (phase two project deployment and billing) are not a ‘factors’ and are accordingly excluded. They will be considered in the next iteration along with other contextual factors. Also in the next iteration, the comprehensive UTAUT analysis along with hedonic factors will be finalized and presented (covariance-based structural equation modelling).

### Performance and Effort Evaluation.

In the current iteration, the performance and effort expectancy analysis of the end user respondents is as presented in Table 2.

**Table 2.** Performance/Effort: Water quantity, quality, use, learning and understanding

	<b>Water Quantity</b>	<b>Water Quality</b>	<b>Use</b>	<b>Learning</b>	<b>Clear &amp; Un- derstand</b>
<b>Strongly Agree</b>	18.2	27.3	18.2	27.27	18.18
<b>Agree</b>	54.5	27.3	27.2	9.1	36.36
<b>Neutral</b>	9.1	36.4	36.4	27.27	27.27
<b>Disagree</b>	9.1	-	18.2	27.27	9.1
<b>Strongly Disagree</b>	9.1	9.0	-	9.1	9.1
<b>Total (n=11)</b>	100	100	100	100	100

In Table 2, it is seen that “Agree” has 54.5% of the water and work staff choice; we can then conclude that the users see IBWQS as a system that can easily detect the quantity of water in a tank. Regarding quality, IBWQS is having 36.4% as “Neutral” which means the respondents couldn’t decide if IBWQS has the capacity to maintain water quality or not. Nonetheless, from the “Agree” and “Strongly Agree” of 27.3% we can conclude that the users see IBWQS as a system that is capable and easy to maintain water quantity. In the same Table 2, “Neutral” has the highest percentage with 36.4% while “Agree” has 27.3%, implying that IBWQS may likely not be easy for them to use or maybe easy. We checked whether IBWQS would be easy for them to learn or not. There was a tie in the decision made by the respondents as “Strongly Agree”, “Neutral” and “Disagree” with 27.3% respectively. This implies, slightly so, that IBWQS is easy to learn; some were undecided while some believed that it is not that easy to learn. Many respondents agreed that IBWQS is a system that would be clear and understandable; indicated by ‘Agree’ having the highest rating of 36.4%.

### Contextual social influence.

The social influence of the new device as perceived by end users was analyzed and presented in Table 3

**Table 3.** Respondent feedback to contextual social influence:

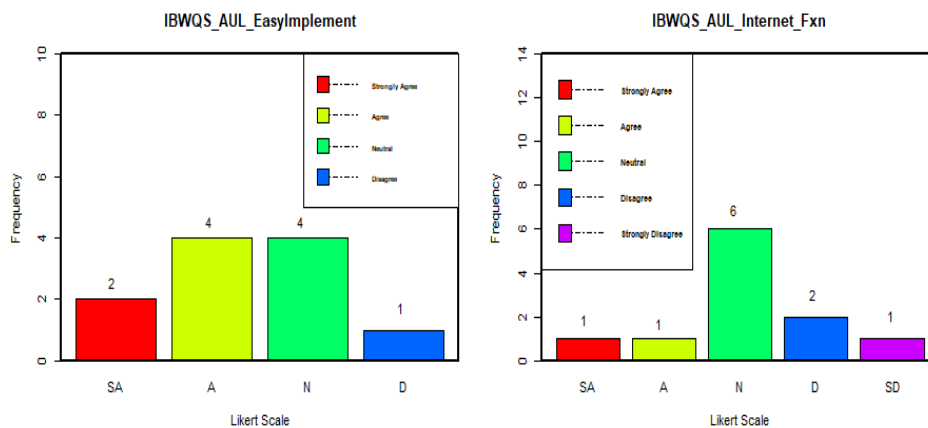
	<b>Institutions</b>	<b>Introduce</b>	<b>Family &amp; Friends</b>	<b>Influencer</b>
<b>Valid Strongly Agree</b>	27.3	27.3	27.27	36.3
<b>Agree</b>	45.5	36.4	36.36	45.5
<b>Neutral</b>	18.2	36.4	18.18	9.1
<b>Disagree</b>	9.1	-	9.1	9.1
<b>Strongly Disagree</b>	-	-	9.1	-
<b>Total (n=11)</b>	100	100	100	100

Gaining understanding of respondents’ opinion to know if the software would be introduced to (higher) institution that needs it, 45.5% agreed with 27.3% further strongly agreeing and a 18.2% neutral. Also, in Table 3, “Agree” and “Neutral” have

the same percentage rating of 36.4 for ‘water and work’ staff choice which indicates that IBWQS may either be introduced to employers or not. Respondents agreed to the fact that IBWQS would definitely be introduced to their family and friends having the highest rating of 36.4%. Respondents overwhelmingly agreed to the fact that if an important or influential person introduces the IBWQS system to them, they would adhere and implement the system; indicated by ‘Agree’ having the highest rating of 45.5% and another 36.4% strongly agreeing.

### Facilitative conditions in the context of the university reality.

Respondents’ responses to the UTAUT constructs are presented in the charts in Fig. 8. For the two facilitating conditions as analyzed the degree of implementation indicate “Agree” and “Neutral” are tied with 36.4% respectively which means that some agreed to the fact that IBWQS system has an easily implementable system while some are indifferent about the system been an implementable system or not. Finally, the respondents are “Neutral” with 54.5% rating and 18.2% disagreement that IBWQS functions properly.



**Fig. 8.** Chart showing different usage systems with different functions regarding to water

The charts indicate each of the ratings clearly with respect to the IBWQS system usage. In summary, a critical analysis of the UTUAT constructs clearly shows the auspicious utilitarian value of the system with respect to the perception of end users who participated in the acceptance and use of technology analysis.

The response from the small pool of end-users shows a favourable disposition to the IoT-based water quality system. The performance expectancy, an indication of the belief that the end-users hold, and the effort expectancy, a degree of usefulness, are relatively encouraging.

Further compensating evaluation would be considered in future: such as system usability scale (SUS), heuristic evaluation, contextual interview, or hybrid.

### 4.3 Implication for research and practice

Reticulation of water for domestic use could be a source of concern when there are no efficient measures to ensure a proactive system of management and distribution. Lack of portable water for daily use, and the sudden realization of shortage could disrupt daily productive activities of people who cannot do without portable water for food, cleanliness etc. The indispensable nature of water therefore calls for proactive measures towards water distribution and quality assurance policies, per SDG No 6.

In the academic environment of the Anchor University, Lagos, this study conceptualizes an IoT-based water quantity control and quality assurance system that alerts on the possibility of water shortage and the safety status of water for consumption. The system was implemented using the build, process and experimental methodology to design and implement the proposed framework. The UTAUT framework, with its recent update, encouraging contextualization, remains versatile in ascertaining the performance and effort expectancy analysis of the system alongside the social influence and the facilitating conditions. Researchers should, while contextualizing projects such as our IBWQS pay attention to underlying mechanisms. In the next iteration, greater attention will be given to the contextual setting of IBWQS within the university settings and the larger community, as well as unearthing generative mechanisms in the socio-technical setting [26].

## 5 Conclusion and recommendation

The water quality monitoring system was deployed in a single institution. The implementation and evaluation were based on the contextual intricacies of the specific institution. Nonetheless, this limitation, the findings provide a rich bed for investigating how water monitoring system can be deployed within an institution in a mega city of a third-world country. Lessons learnt from this adoption are infallible factors towards the United Nations SDG goal 4 and ICT4D researchers/practitioners.

We reported the design, deployment, and evaluation of an IoT based water monitoring system (IBWQS) in a university environment. The UTAUT-based analysis shows a favourable disposition of end users to the solution. We nonetheless note some lapses. Consequently, future study, of larger pool of users, is expected to incorporate the daily consumption rate of water volume as a proactive measure towards making enough provision to last specific timelines. We hope to undertake future research work from socio-technical, systems and complexity theory stand view. Our goal is to explicate underlying contextual causal mechanism towards deepening IT/IS adoption and penetration. In so doing, we frame and factor transformative and emancipatory ethos as espoused in axiology of critical realism [26].

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