Application of Real-World Simulation: A Bridge between Theory and Practice in Higher Education in Nigeria.

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Abstract: *Bridging the gap between practical application of technology in industries and the theory learned in class room is challenging especially when preparing students for the rigor of working in industries. Various methods of teaching applied science students has been devised such as software-based simulation to provide a teaching aid, but most of them failed to deliver a realistic practical understanding that would immediately transform theory into practice in our class rooms. In this paper, a simple, inexpensive, reliable but effective approach has been developed to convey both theoretical and hands-on industry practice of interface programming in visual environment to applied science and engineering students using a real-world simulation of flow processes of a petrochemical instrumentation and control.*

Keywords: *Universal Modelling language(UML);Process instrumentation;Parallel Port; Printed Circuit Board; Decoding and Encoding addressing unit.*

I. Introduction

With the fast evolving industrial innovations and advances in process instrumentation, the need to create an effective teaching tools for applied science and engineering students to aid them in understanding the dynamics of Oil and Gas instrumentation landscape would help to narrow the gab between theory and practice in Nigerian schools. According to educology of scientific education, which emphasizes on the effective application of teaching process and study, science and engineering students require appropriate structural guidance in practical skills acquisition (Ango, 2002). Instructional teaching through the use of pedagogic approach of a combined theory and experimentation has been advocated as an effective way of teaching sciences in both secondary schools, colleges and universities (Afemikhe et al., n.d, Chuckwuka, et al., 2014, Eze et al., 2015). This is because teaching hands-on skills in higher education in Nigeria with the view of applying science in solving real world problems creates "discovery-reception continuum as against meaningful role learning experience" (Ausubel, 1968 as cited by Ango,2002). In developed nations where higher education is strengthened, there are intensive collaborations between industries and colleges of higher learning to continue to support students with equipment and tools to tackle real world challenges for the development of critical sectors of the nation. This allows students to acquire wide range of technical skills to help them in expanding the boundaries of technology and scientific applications through innovations. In most of the African countries especially Nigeria, unstable political landscape and poor funding have led to the shortages of instructional materials, essential laboratory equipment and inadequate human resources, which have continued to degrade the quality of practical skills acquisition in institutions, technical colleges, polytechnics and universities (Moja, 2000; Okolocha, 2012). These problems can negatively affect the technological growth and industrial development as a whole. A study conducted by Adesina (2013) attributed lack of vocational and technical education as one of the major causes of unemployment in the country and a source of insecurity due to the growing number of jobless youths in the streets. This implies that practical skills acquisition, the one that combines both theory and applications, does not only bridge the gap between theory and industrial applications but also provide a career boost to students and accelerate industrial development of a nation (Ogbuanya and Okoli, 2014; JeanClaude, 2003). Therefore, building sound working knowledge and practical competencies at school will help to minimize training of personnel, extend the quality of understanding sciences, improve efficiency of staff, and increase the productivity of an organisations as well as the development of sustainable, dependable and employable learners in Nigeria (Ango, 2002; Eze et al., 2015).

II. Challenges in developing practical skills in Higher education in Nigeria

In spite of the national policies on technical education and practical skills acquisition in Nigerian institutions, various impediments such as insufficient funding, lack of expertise, inadequate practical equipment and poorly conceived educational roadmaps have slow down its implementation. These factors collectively degrade quality of skills acquisition and expertise required to work in industries and manufacturing plants.

Inadequate funding of institutions has been a major bottle-neck in the realization of full academic excellence and quality of education in universities and colleges, which includes accessibility of technical skills and availability instructional materials (Asiya, 2013). This can affect the institutions' ability to hire well trained and qualified teaching personnel to deliver the right skills to students. For engineering and applied science courses, technical skills are highly essential in promoting innovations and advancing the frontier of technical development in organisations. Without the right training and practical skills, students are at risk of unemployment especially where hands-on skills are essential indicators for employment. In 2015, a remarkable result was obtained from a survey conducted in colleges of education Warri (COEWA) and Agbor (COEA) of Delta state with the aim of measuring students' perceptions on the impediments of technical and vocational education and training (TVET) (Serumu, 2015). The result is summarised in the table below.

Table 1. Student Perception on government factors that affect the implementation of Technical education (Serumu, 2015).

S/N	ITEM STATEMENT	COEWA STUDENTS			COEA STUDENTS		
	Government Factors	**Mean**	**S.D**	**Remark**	**Mean**	**S.D**	**Remark**
1.	Poor provision of infrastructural facilities such as library, classroom blocks, workshops, laboratories and recreational facilities.	2.96	1.17	Agree	3.57	0.49	Agree
2.	Poor provision of TVET consumable materials	3.24	0.75	Agree	3.26	0.73	Agree
3.	Poor provision of qualified TVET lecturers.	3.22	0.87	Agree	3.27	0.48	Agree
4.	Poor funding of the TVET programme.	3.12	0.57	Agree	2.57	0.65	Agree
5.	Poor governmental policy on TVET.	3.05	1.12	Agree	3.50	0.74	Agree
	Grand Mean and S.D	**4.68**	**0.51**		**4.33**	**1.12**	

Over the years, funding to tertiary institutions has declined significantly in relation to the number of students' enrolment and infrastructures available, which affect the delivery of quality vocational and technical education in Nigeria especially in public schools and colleges. One of the reasons for the decline in educational allocation was partly attributed to the mono-economic structure of Nigeria and instability in global oil prices (Jaja, 2013). Tables below show the education tax fund (ETF) allocation to tertiary institution from 1999 to 2010.

Table 2. Summary of EFT allocation from 1999-2010 to tertiary institution (Jaja, 2013; Ugwuanyi, 2014).

Yrs	University (N)	Colleges of Education (N)	Polytechnics (N)	Total(N)
1999	2,124,999,960.12	1,099,137,930.00	1,087,209,288.00	4,311,347,178.12
2000	1,050,000,000.00	520,000,000.00	450,000,000.00	2,020,000,000.00
2001	1,794,128,000.00	1,108,048,500.00	967,500,000.00	3,869,676,500.00
2002	3,243,500,000.00	1,742,625,000.00	1,642,500,000.00	6,628,625,000.00
2003	1,440,500,000.00	678,625,000.00	634,500,000.00	2,753,625,000.00
2004	1,515,750,000.00	744,625,000.00	722,750,000.00	2,983,125,000.00
2005	2,025,000,000.00	1,249,000,000.00	1,657,500,000.00	4,931,500,000.00
2006	2,475,000,000.00	1,240,000,000.00	1,302,000,000.00	5,017,000,000.00
2007	3,659,000,000.00	1,579,900,000.00	1,430,000,000.00	6,668,900,000.00
2008	7,112,000,000.00	3,824,160,000.00	3,611,520,000.00	14,547,680,000.00
2009	6,858,000,000.00	3,760,920,000.00	3,472,320,000.00	14,091,240,000.00
2010	16,672,700,000.00	9,587,370,000.00	9,055,000,000.00	35,315,070,000.00

Source: Federal Ministry of Education, Abuja as in Shu'ara 2010.

Table3. Summary of EFT allocation to tertiary institution in percentage (Ugwuanyi, 2014).

Years	University	Polytechnics	Colleges of Education
1999	49.29	25.22	25.49
2000	51.98	22.28	25.74
2001	46.36	25.00	28.63
2002	48.93	24.78	26.29
2003	52.31	23.04	24.64
2004	50.81	24.23	24.96
2005	41.06	33.61	25.33
2006	49.33	25.95	24.72
2007	54.87	21.44	23.69
2008	48.89	24.83	26.29
2009	48.67	24.64	26.69
2010	47.21	25.64	27.15
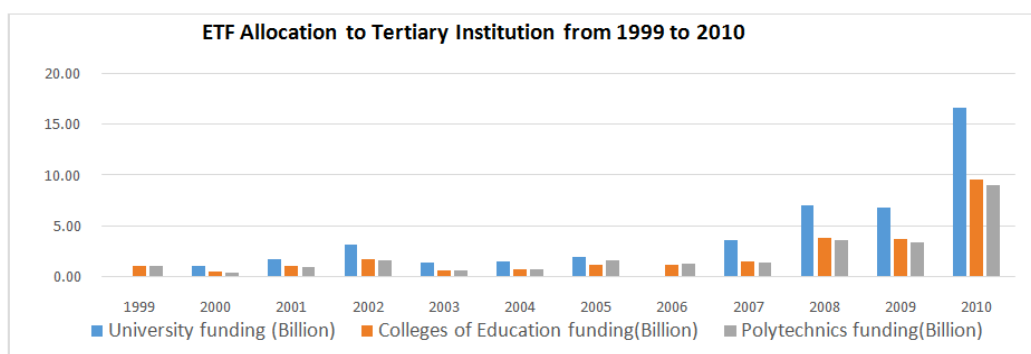
Fig 1. Bar-chart representation of EFT funding to tertiary institution

In view of the above challenges affecting technical education in Nigeria and high cost of getting foreign made practical equipment, locally produced or improvised practical equipment has been advocated to encourage and support local production (Onasanya and Omosewo,2011). This initiative will help to accelerate skill acquisitions and availability of practical tools. With the availability of digital media and audio-visual tools, a new learning paradigm was created, which can be explored as a cost effective way of demonstrating practical task through playing pre-recorded sessions. Over the years, powerful design, modelling and simulation packages, which provides a platform for students to simulate real world problem in a virtual computer environment, have emerged to aid applied science and engineering students in understanding abstract ideas and problem dynamics (Turon el al., 2005). However, these methodologies proved inadequate in providing hands-on experience to students in applied sciences and engineering.

III.   Use of computer simulation in education

The increasing low cost of computing hardware and its associated software has motivated the development of modelling and simulation packages in education. Before the application of modelling and simulation packages in education, aviation industries have been using simulators to train both commercial and military pilots in basic flight training and psycho-motor tasks (Kincaid and Westerlund, 2009). This method practically save cost, minimise accidents due to human-error and improve general safety in aviation industries. The overall success and effectiveness of simulation in aviation made it possible to extend the application to other field of studies. In the field of medicine, a simulation-based approach using software-hardware configurations has been used to teach surgical procedures and practices of medical emergencies in higher education (Weller, 2004; Kincaid and Westerlund, 2009). This approach allows students to train their cognitive and motor skills in performing various medical techniques on patients. Additionally, the use of visual simulation, in a practical sense, simplifies complex phenomenon and help students to understand dynamic process (Stancic et al., 2007). The use of computer simulation significantly increases practical skills, broaden analytical thinking, improve performance and general awareness of students on a subject matter. It presents to students a realistic tool for acquisition of skills and a platform for cost effective problem solving within their domain and area of specialization. Modelling and simulation in teaching could be classified as physical simulation, interactive simulation or computer simulation (Turon el al., 2005; Stancic et al., 2007).

Table 4. Taxonomy of Modelling and Simulation Professional knowledge by Discipline (Kincaid and Westerlund, 2009).

	Topic	Simulation Model Developer	Scientist/ Experimenter	Instructional Simulation Developer
Math & Physics	Numerical Analysis	Low	High	Medium
	Statistics	Medium	High	Medium
	Linear Algebra		Medium	
	Differential Equations	Low	Medium	Low
	Dynamics		Low	
	Electric Circuits		Low	
Industrial Engineering	Programming	Low	High	Low
	Nonlinear Optimization	Low	High	
	Sensitivity Analysis	Low	High	
	Cost Models	Medium	Low	Low
Human Factors	User Interface Design	High	High	High
	Training Theory	Medium	High	High
	Usability Testing			High
Software Engineering	Modular Program Design	High	High	
	Verification & Validation	High		Medium
	Testing	High	Low	Medium
	Metrics	High		
Computer Science	Database Systems	High	Medium	
	Operating Systems	High	Medium	
	Computer Networks	High	Low	
	Distributed Systems	High	Low	Low
	Artificial Intelligence	Medium	Low	
Instructional Technology	Instructional System Design			High
	Media Selection			High
	Task Analysis	Medium		High
	Instructional Evaluation			High
	Learning Theory			High

Despite the impressive benefits of modelling and simulation such as cost effectiveness, and analysing complex situations that might proved costly to experiment in real-life, there are challenges in mapping the right simulation to meet specific and specialised learning needs (Kincaid and Westerlund, 2009). This can be a problem in terms of meeting a given learning objectives in relations to a chosen field of studies. A study reviewed on the use of simulator as a training tool revealed that while simulation has proven effective, there is a need to further investigate how and why it works (Salas and Canon-Bower, 2000). Furthermore, the problem of lack of modelling and simulation professional need to be address to encourage effective transfer of technical skills to students (Turon el al., 2005).

In view of the challenges facing the development of teaching aid in higher education, we explore the practicality of realistic small scale modelling of a process instrumentations, computer technology and digital control to provide a platform where students can conceptualise, design and implement ideas in the area of industrial instrumentation and control. The method of physical simulation in real world is adopted in this work which involve the steps of building a small scale model of instrumentation system, and integrate it with computer technology to deliver a practical experience in interface programming and process control. The philosophy of this approach is centred on building a practical skills through the use of cost effective and easy to implement Teaching Aid System (TAS). Using this teaching methodology, student can quickly develop different graphical user interface (GUI) of Oil and Gas instrumentation flow process to work with a custom build hardware interface for controlling external systems with minimum configurations.

IV. System structure and design of the Process instrumentation teaching aid

The detailed analysis and design of various components that collectively made-up the software are outlined in this section. Different presentation techniques are employed to provide clear perspectives on the system architecture and composition. We explored the use of unified modelling language (UML) for the design and representation of the teaching aid system into different views. In general, unified modelling language provides a system designer working on analysis and design with one consistent language for specifying, visualizing, creating and documenting software artefacts (Almendros-Jimenez and Iribarne, 2007). This helps to graphically show relationship between sub-systems and their interaction while abstracting low level details from the model.
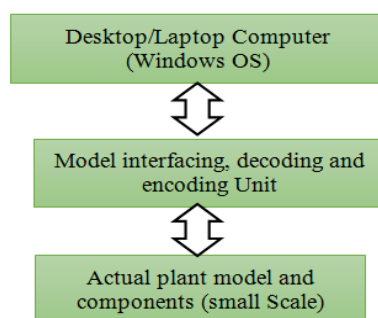
Desktop/Laptop Computer (Windows OS)

Model interfacing, decoding and encoding Unit

Actual plant model and components (small Scale)

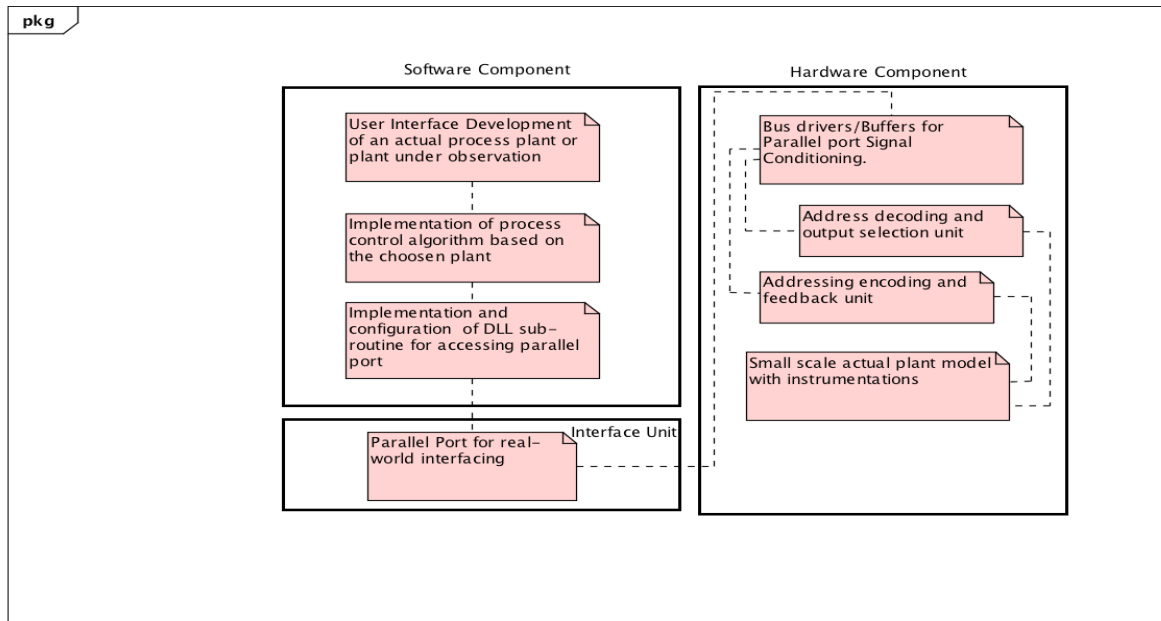**Fig. 1.** Block diagram of Process Control Teaching aid (TAS).

Fig.2. Process control Teaching Aid Main Processes.

4.1. Use-Case

Use-case diagram is seen as a validation model used in representing the structure and dynamics process of a system. It is the most commonly used software modelling artefacts during requirement analysis and information gathering of a software lifecycle (Srisura and Daengdej, 2010). The Use-case is verified as an expressive conceptualization of the central phenomenon in design process, and contribute to establishing scholarly structure and activities (Mutschke et al., 2011). This simplify system behavioural modelling and describes interaction between various components of the activity diagram (Almendros-Jimenez and Iribarne, 2007). In fig. 3 below, the major components of the teaching aid have been described with great abstraction. The plant control software is represented by an actor which composed of a user interface, dynamic link library, control algorithm and parallel port. Each oval represents a functional part of the application and their roles as described in the Use-case diagram.
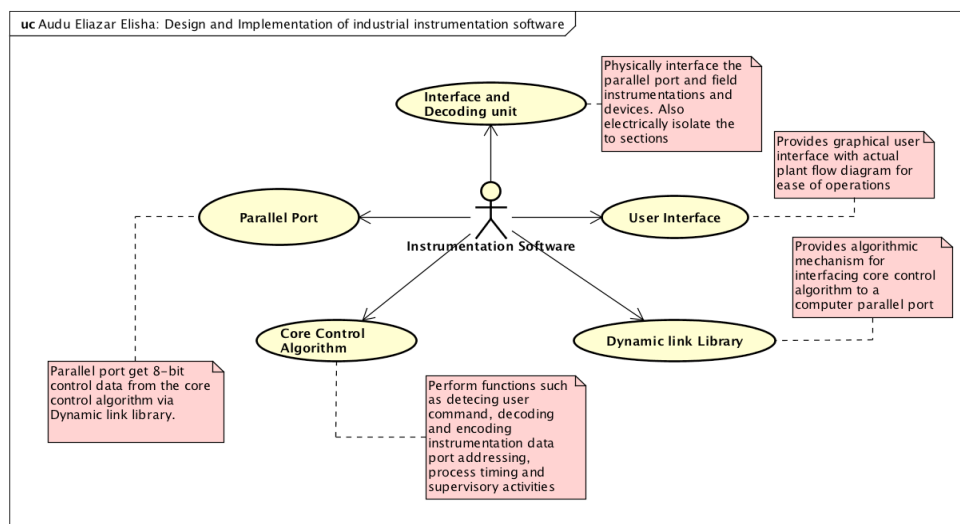

Fig. 3. Use-case Diagram of the Process Control Teaching aid

2.2 Sequence diagram

The interaction between various components of the system is described using sequence diagram. It captures the interaction between objects in the context of collaboration and visually show object methods that

play roles in the system (Felici, 2011). The essence is to convey how the entire system works by describing the movement of task between objects with great abstraction. This helps to explain the logic of the system and established the understanding about the system functionality. This diagram is employed to graphically show the flow of action from Interface user through graphical user interface to DLL and to the modelled hardware instrumentation system via the interface decoding and encoding circuitry. The communication in the system is bidirectional, and the status of each element in the modelled instrumentation is acquired via the Interfacing and decoding unit to update the interface.
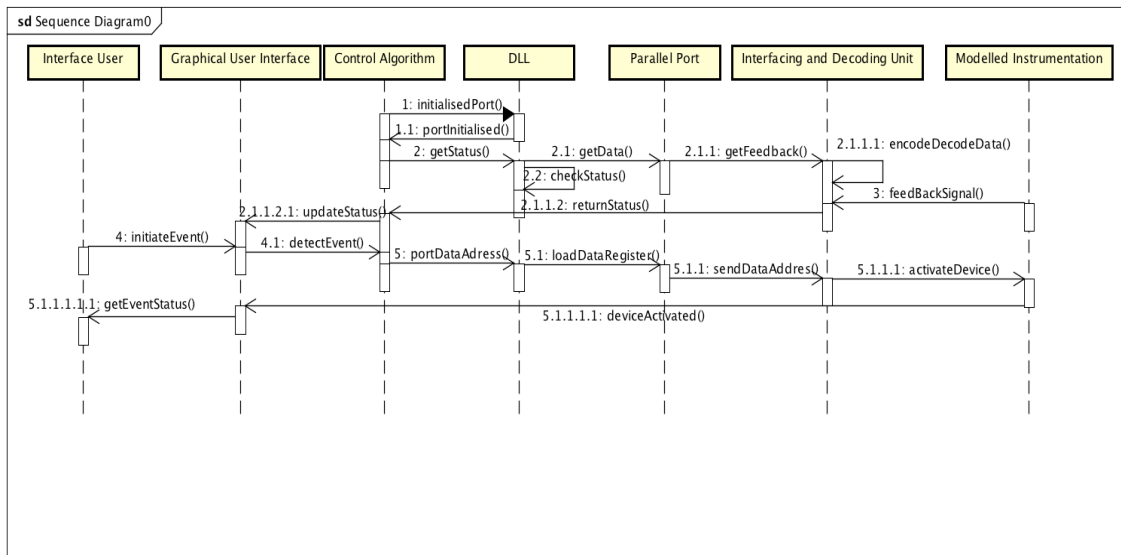
Fig. 4. Sequence Diagram of the Process Control Teaching aid.

The design basically consists of seven layers participating in the interaction namely the Interface user, graphical user interface, control algorithm, DLL, Parallel port, Interfacing and decoding unit and the instrumentation model. The columns of the diagram represent the time component while the vertical lines are the interaction between each unit. In this case, students represent the Interface user and the graphical user interface consists of the actual flow diagram of the modelled instrumentation. Control algorithm depend on the structure of the plants and flow diagram. The DLL provides a software interface between the user application program and the parallel port to control external devices.

2.3 Class Diagram
The class diagram representation provides high level description of the teaching aid system, which facilitate the developer's ability to easily examine the entities and their relationships in the software system (Nanthamornphong et al., 2015). In addition, it supports better comprehension than entities relation (ER) especially in the absence of documentation of software system (Al-Shamaih, 2015). Fig 5 below shows how each software component fits into a class with their attributes, data types and operations. This made it easy to understand the structure and function of the software as well as transfer of data from one class to another, which includes operations that would be performed on the data. In the figure below, user interface provides a mechanism through which the software portion interacts with the modelled instrumentation system. The attributes and data type in the user interface are clearly specified, and the operations on them. Operations in a class are basically methods that interfaces with other classes of the software system, creating a tunnel of information between them. The concept of classes allows software be modelled in object oriented structures and encourage reusability and ease of modification as stressed by software engineering principles.
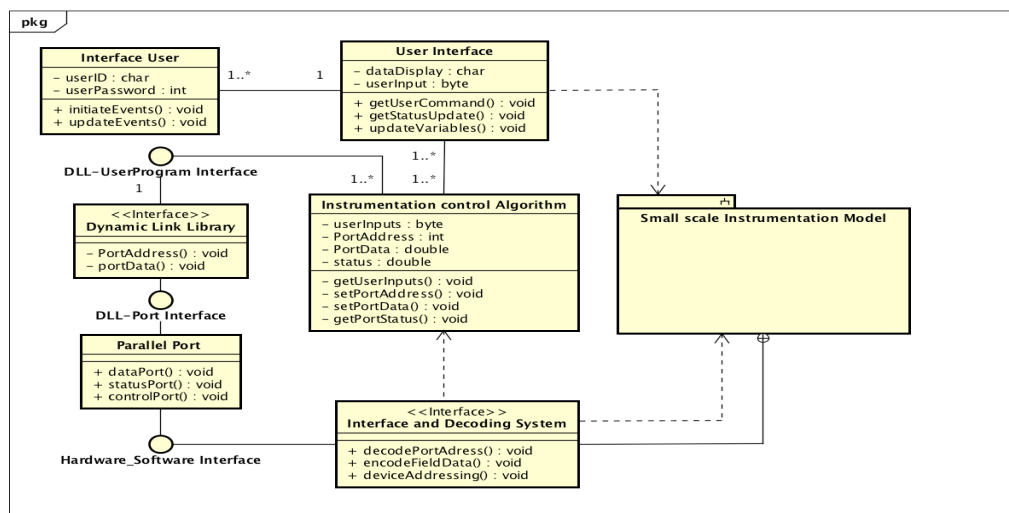
Fig. 5. Class diagram of the Process Control Teaching aid

V. Method, Implementation and Results

In developing this practical learning aid, visual basic environment was used as a platform for implementing the instrumentation control application. Visual basic was developed by Microsoft and is one of the most popular languages for programming PCs. The language provides visual tools, templates or forms for writing an application programs and sets of routines that simplify external application (hardware) interfacing programming (Axelson, 2000). It provides a rich library of visual tools for drawing the actual process elements and flow processes using various shapes and buttons. Additionally, it is easy to learn and quickly develop prototypes of an applications with powerful data visualization methods. This made it a good environment for learners to develop applications with attractive graphical user interfaces (GUI). Using visual basic, different process flow interfaces can be designed based on the physical configuration of a physical modelled plant and allow students to conceptualise, design and implement their own industrial control systems. This approach is part of the adoption of visual learning literacy in teaching with the aim of increasing the degree of good learning outcome, provides a deeper insight and capacity to communicate effectively, instantly and universally (Stokes, 2001; Metros, 2008).

5.1 Graphical User Interface

The interface is an interactive graphical user interface designed to contain the actual process flow diagram. The use of actual flow diagram of a process as opposed to command is to enhance usability and interaction. Furthermore, it allows visual tracking of process activities and offer a quick overview of the entire plant, and aid students in building a robust model of a process instrumentation systems using visual programming environment. Command buttons are used to initiate event driven activities by the system user such as opening valves, operating motors or activating actuators. Figure 6 below shows the actual GUI implementation of a petrochemical instrumentation and control system. This approach does not only allow students to rapidly prototype instrumentation systems but also aid in understanding various system interconnection and dependency in process control and instrumentation. The use of visual construct in mimicking switches, buttons and boxes speedup learning and provides intuitive method for interacting with the teaching aid (Toby, 2001).
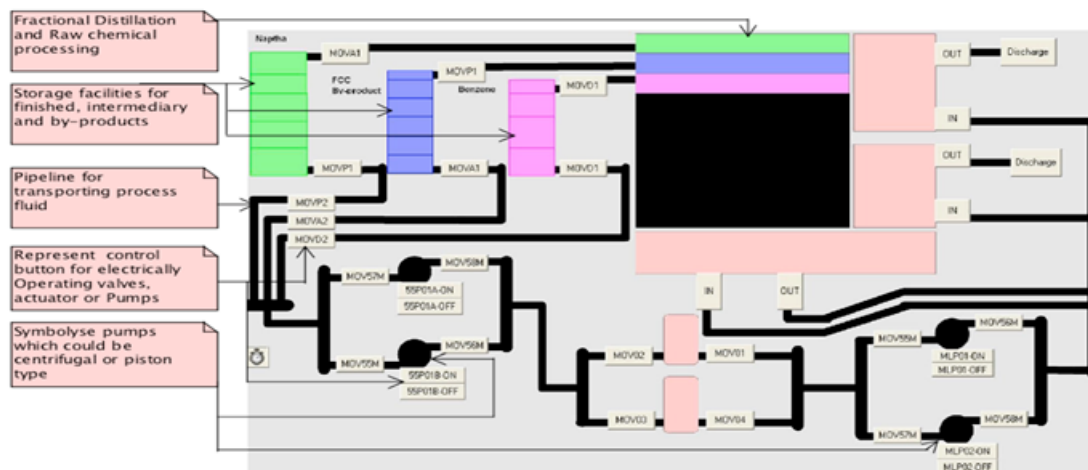
Fig. 6. Graphical User-interface of the Process Control Teaching Aid implemented.

As shown above, the design of the process plant model provides a practical view of the entire flow process and major instrumentations that control the plant.Each equipment is labled with a number as part of the world-wide industry culture for cataloguing and grouping of equipment for easy referencing. This practice encourage student to learn the accepted norms in designing instrumentation systems and control interface programming.
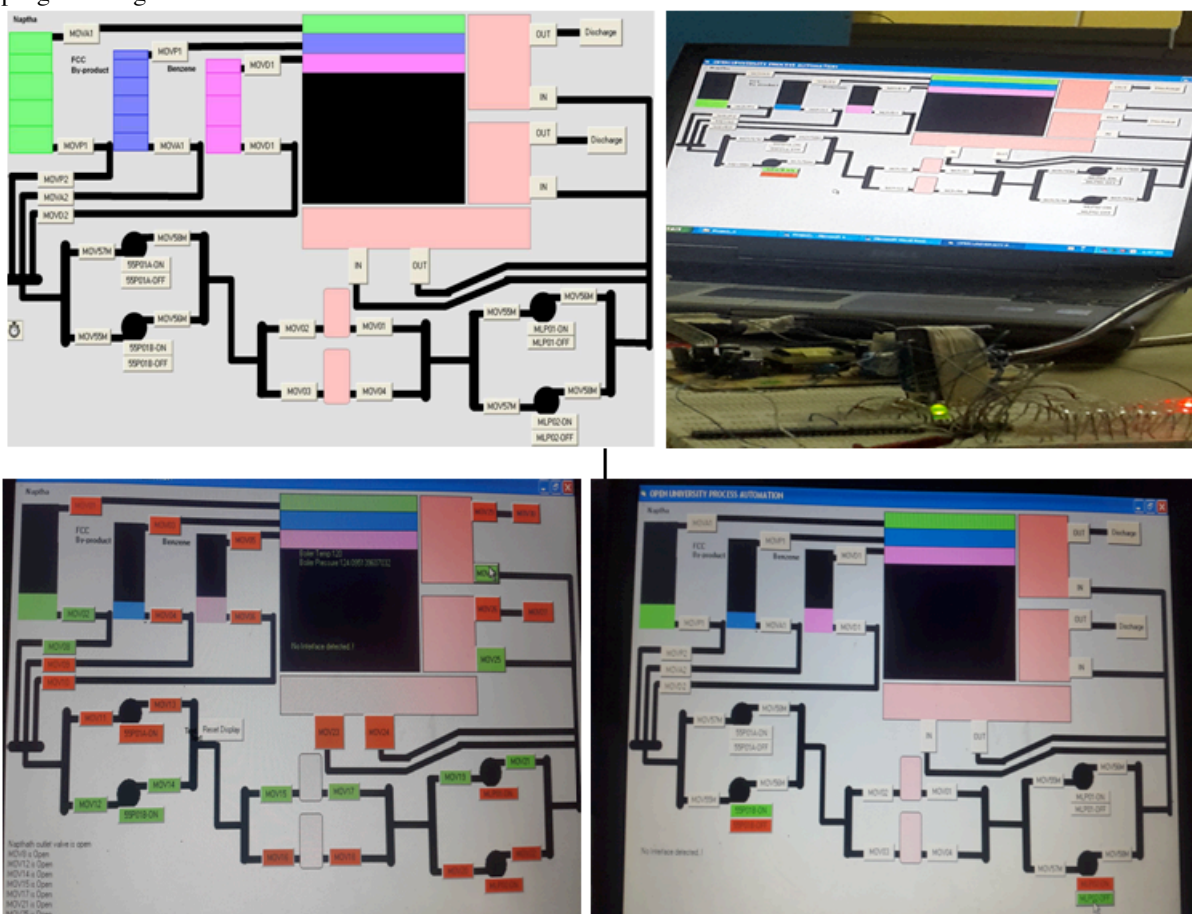

Fig. 7 Actual view of the implemented GUI for a petrochemical process by a student.

In the GUI, "GREEN" buttons indicates active equipment while the "RED" buttons indicates inactive devices (OFF). MOVs represent valves, 55P01 stands for booster pump and MLP reprsents Main line pump. The left hand corner of the GUI displayed status of the system for quick visualization and tracking of active activities.

5.2 Hardware and Interfacing Unit

The Interfacing, decoding and encoding (IDE) unit is a specifically designed system to provide hardware interfacing functionalities between computer port and the modelled instrumentation system. It allows the instrumentation control software to individually addressed each equipment or sensor of the plant by de-multiplexing parallel port signals. Additionally, it encodes feedback signal from the external model board using 16-to-4 addressable encoder to the PC for reading equipment status. Besides decoding and encoding of addresses, the interfacing unit electrically isolate the port from the external circuitry to prevent damage to the port from short-circuits or excessive current sinking by external loads. In this design and implementation, the IDE unit can address (control) 32- individual external loads and encode 32-individual feedback signal from the modelled plant. Scalability is possible by logically cascading more IDEs to expand the addressing lines. The dynamic link library (DLL) allows the software to interact with the IDE unit to control the external modelled instrumentation system of the petrochemical plant from the graphical user interface console.
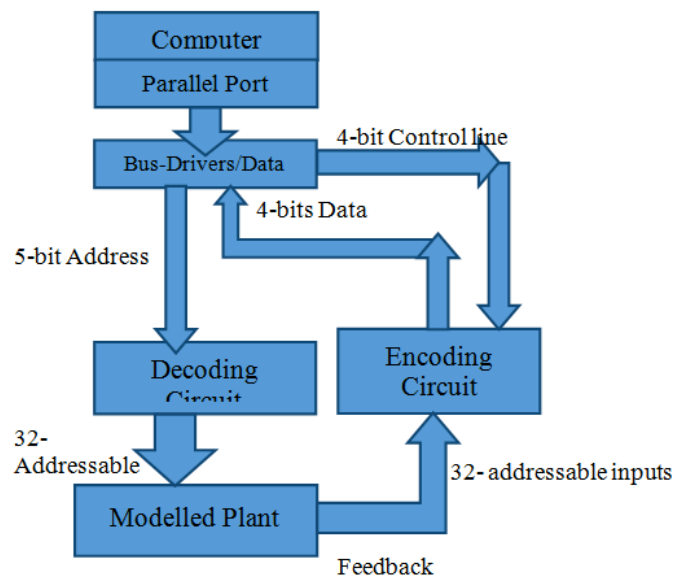

Fig.8. Interfacing data and Address communication bus-widths and hardware sub-sections.

To interface a PC and IDE circuitry, a parallel port is adopted for its simplicity and ease of implementation. Parallel port was specifically designed under IEEE 1284 specifications for data transfer between a printer and a PC or other external devices. It is part of the PCs ports that CPU use for communicating with other peripheral such as modems, memory, keyboards, and displays. There are three port registers operating at TTL logic levels that collectively formed parallel port communication port. These are data register, status register and control registers at addresses 888, 889 and 890 respectively.

Table 5. Pin designation and their function of DB-25 and Centronics parallel port (Peacock, 1998).

Pin No (D-Type 25)	Pin No (Centronics)	SPP Signal	Direction In/out	Register	Hardware Inverted
1	1	nStrobe	In/Out	Control	Yes
2	2	Data 0	Out	Data	
3	3	Data 1	Out	Data	
4	4	Data 2	Out	Data	
5	5	Data 3	Out	Data	
6	6	Data 4	Out	Data	
7	7	Data 5	Out	Data	
8	8	Data 6	Out	Data	
9	9	Data 7	Out	Data	
10	10	nAck	In	Status	
11	11	Busy	In	Status	Yes
12	12	Paper-Out PaperEnd	In	Status	
13	13	Select	In	Status	
14	14	nAuto-Linefeed	In/Out	Control	Yes
15	32	nError / nFault	In	Status	
16	31	nInitialize	In/Out	Control	
17	36	nSelect-Printer nSelect-In	In/Out	Control	Yes
18 - 25	19-30	Ground	Gnd		

Another advantage of parallel port in data transfer is synchronous parallelism where several bits (8-bits) can be clocked at the same time instead of serially. This simplifies the design of the address decoding circuitry and reduces the complexity of the IDE unit, which significantly reduced implementation cost.
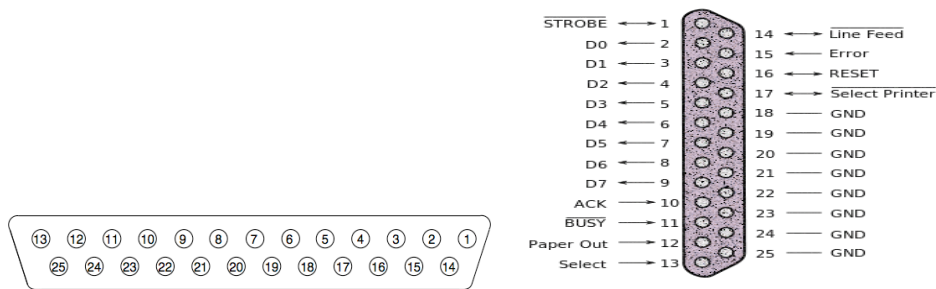
Fig 9. DB-25 Connector and Pin assignment for parallel port (Peacock, 1998).

In the actual implementation, the IDE unit consist of octal bus drivers that improve the source –sink current of parallel port to meet the load current requirement and prevent the internal registers of the port from damaging. To drive the actual small scale model of our instrumentation flow diagram, optocouplers together with triac are used to drive contactors for pumps and actuators while the address decoding circuit is centred around 74HCT138 decoder and 74HCT245 integrated circuits. Figure 9 below shows the PCB design and implementation.
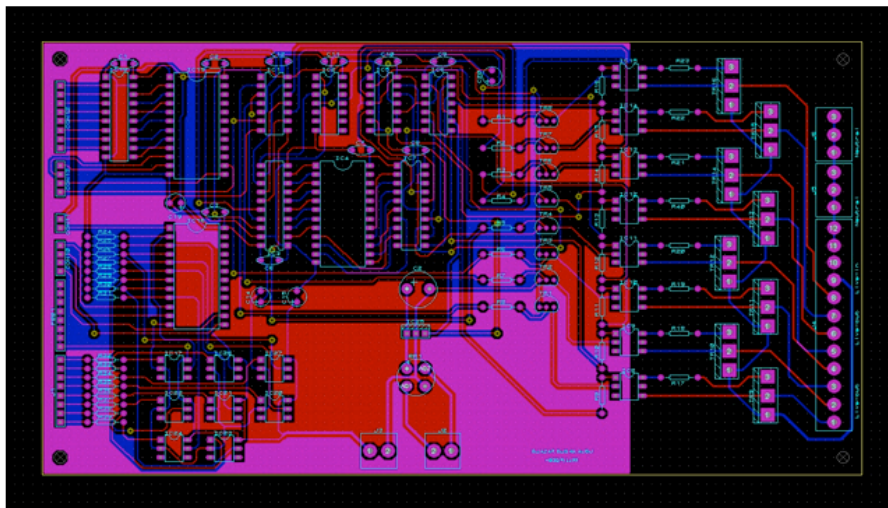

Fig. 10. The designed Printed Circuit Board for the Interfacing and decoding unit.
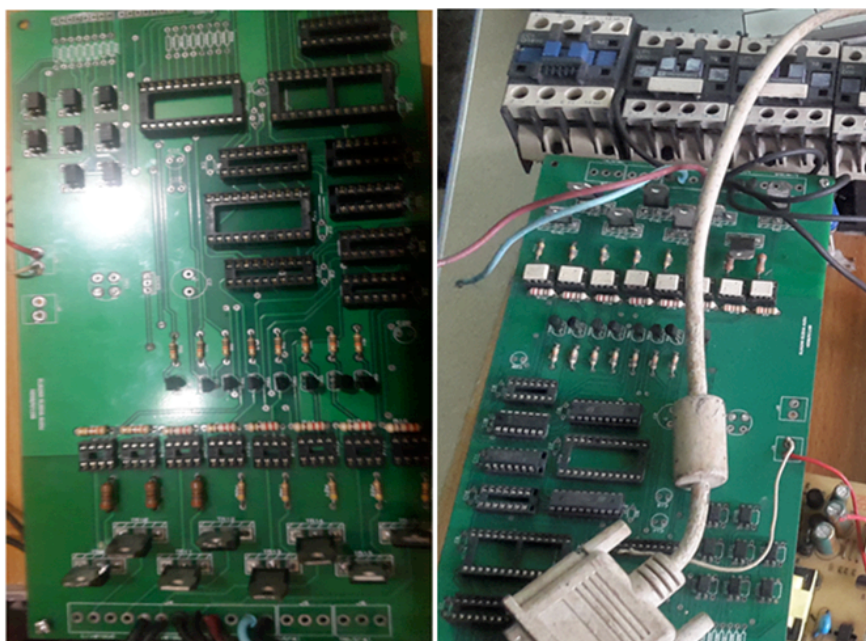

Fig. 10. The the actual printed circuit board of the Interfacing and decoding unit.

The IDE unit allows students to choose their own hardware configurations based on their modelled plant to meet individual custom GUI design. This flexibility implies that the same hardware can be tailored to meet different ideas in process automation and control implementation, and the parallel port offered a simple, effective and easy to design interfacing unit without complex address decoding and encoding circuitry.

5.3 Interfacing and Configurations

Visual basic lack inbuilt routines (or DLL) for applications to directly access communications port at hardware level. However, it has in-built methods that allow easy integration of independent DLL programs into an application that intend to control external devices. In this case, we use a third party widely used parallel port DLL, inpout32.dll, which can be accessed by Windows programs and Windows OS. Using this DLL, only two variables are required to pass or receive data through the parallel port. The variables are **nPort** and **nData** both declared as Integers. **nPort** defines port address while **nData** contains data to be sent to a port address, and each of the three register of a parallel port can be accessed by declaring and using the following simple statements:

```
Private Declare Function Inp Lib "inpout32.dll" Alias "Inp32" _ (ByVal PortAddress As Integer) As Integer
Private Declare Sub Out Lib "inpout32.dll" Alias "Out32" _ (ByVal PortAddress As Integer, ByVal Value As Integer)

Dim receivedValue as byte
Dim sentValue as byte.

Out PortAddress, sentValue          //General command for sending data to parallel port
ReceivedValue=Inp(PortAddress) // General command for receiving data from port
```

Once the initial application is configured, modification on the GUI interface, and hardware interfacing and decoding unit can be made without affecting the configurations of the DLL. This make it easier for students to focus on designing their own interfaces and control algorithm without the need for re-configuration.

VI.   Conclusions

Our approach to building teaching aid for applied science and engineering students is based on the application of physical (real world) modelling and simulation, which is essential for developing both hands-on skills and theoretic aspect of system design and applications. It provides a platform where students can interact directly with real world components to develop a working concept in industrial instrumentation and control using computer technology. Through the use of parallel port and visual basic programming environment, process prototypes can be developed quickly, and tested using efficient, inexpensive and simple to use external hardware interfacing unit. The teaching aid described in this paper offers great flexibility for students to tailor their own ideas and realize with easy to use starter tool for instrumentation, interface programming and digital control especially in cases where there is budgets constrained and low funding. Visual basic is easy to learn and develop application prototype with wide range of visual tools and attributes and parallel port, as an interfacing port, simplifies interface configurations and reduce complexity of the external hardware interfacing, decoding and encoding circuitry.

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