



Research in Engineering Education Symposium (REES)
Regional Conference in Engineering Education (RCEE)
& Research in Higher Education (RHed)
September 29 – October 3, 2025
Johor, Malaysia



Deployment of Computer-Aided Learning Programs for Effective Learning in Crucial Chemical Engineering Courses for Bachelor of Engineering in Chemical Engineering Degree Programme

Umar Isah Abubakar^{a,b}

Product and Process Development (PPD) Research Group, Department of Chemical Engineering, Faculty of Engineering, Ahmadu Bello University, Zaria, Nigeria

*^bDepartment of Chemical Engineering, Faculty of Engineering, Ahmadu Bello University Zaria, Nigeria
iamumar@abu.edu.ng*

ABSTRACT

BACKGROUND & CONTEXT

Core Chemical Engineering (ChEC) courses such as Process Dynamics and Control (CHEN 502) and Chemical Reaction Engineering I (CHEN 407) are commonly taught using deductive approaches with simplifying assumptions, limiting students' ability to address complex real-world engineering problems.

PURPOSE OR GOAL

This paper presents the implementation of computer-aided learning programs (CALPs) in undergraduate ChEC courses to promote student-centred learning. Specialized commercial software was used to support cooperative and peer learning through project-based learning (PjBL) in CHEN 502 and problem-based learning (PBL) in CHEN 407 at Ahmadu Bello University, Zaria, Nigeria.

APPROACH OR METHODOLOGY

A mixed-methods design was adopted, combining quantitative analysis of performance indicators with qualitative survey data. Questionnaires were administered to multiple student cohorts enrolled in CHEN 502 and CHEN 407 between the 2008/2009 and 2010/2011 academic sessions to evaluate the impact of CALPs in collaborative learning environments.

OUTCOMES

Results were analysed using mean scores and standard deviations, followed by interpretative discussion. Students' responses across both courses were ranked and learning gains were evaluated based on the attainment of course learning outcomes (CLOs).

CONCLUSIONS

Findings from the 2009/2010 and 2010/2011 sessions indicate that most CLOs were successfully achieved, demonstrating the effectiveness of CALP-supported cooperative and problem-based learning approaches.

KEYWORDS

Computer-aided learning programs, Process Dynamics and Control, Chemical Reaction Engineering I.

Introduction

There is a need for paradigm shift in educating Undergraduate students the fundamental concepts of some of the crucial Chemical Engineering courses such as the Introduction to Process Dynamics and Control (CHEN 502), and Chemical Reaction Engineering (CHEN 407) handled and administered at the Department of Chemical Engineering, Ahmadu Bello University, Zaria and other Departments around the globe similar in contents in the synopsis of these vital courses from the classical conventional deductive learning methods to more logical, active and inductive styles of learning as well as real-time non-traditional approaches (Isah et al. 2022; Isah and Ameh, 2023; Svrcek et al. 2014). This is due to high level of concepts abstraction, their inferiority and simplification by so many assumptions and generalizations of complex real-life situations, and thus, these antique techniques that were developed when the computational capabilities were very poor, cannot be used to address today's real-world complex challenges (Isah et al. 2022; Isah and Ameh, 2023). The inevitability for phasing out the former pedagogical techniques in the current Chemical Engineering curriculum cannot be overemphasized. The reason is that they were developed in Mechanical and Electro-Mechanical Engineering professions where processes are viewed and generally characterized linear with little dead times, involving single or few species for almost 8 decades ago. In addition, it was extremely difficult and impracticable to simultaneously solve multivariable process models with higher order differential equations and high degree of non-linearities analytically or numerically or with the computing aids due to the limitations of both sophisticated computer software, hardware, and storage devices with enough required spaces in those days. This clarion call cannot be overlooked due to the current necessity to meet-up with the requirements of the student-centred teaching and learning of the basic concepts of these critical courses in the same ways they are practised and implemented in the Chemical and Process Industries (CPIs), satisfy the demands of the dynamic labour markets, and the requirements by the program learning outcomes (PLO) (Felder and Brent, 2004; Rugarcia et al., 2000; Felder and Brent, 2016; Felder and Brent, 2003; Prince and Felder, 2006; Prince and Felder, 2007). One of the main objectives of this conference paper is to reveal our recorded success on how the deployment of computer-aided learning programs (CALPs) or tools and modern innovative pedagogies led to more clearer understanding and retentive comprehension of the fundamental concepts and principles of these crucial core courses, the Introduction to Process Dynamics and Control (CHEN 502), and Chemical Reaction Engineering (CHEN 407), impacted on students' preparedness in acquiring practical knowledge, skills, capabilities, and technical know-how prerequisite by the program learning outcomes (PLO) in the curriculum of Bachelor of Engineering in Chemical Engineering for addressing their real-world challenges in the profession of Engineering. Moreover, it was to assist students in developing and improving their cooperative skills for effective teamwork, leadership and communication skills needed for successful practice in their Engineering careers (Isah et al. 2022; Isah and Ameh, 2023). To examine and evaluate whether the students had really attained the expected appropriate knowledge, skills, and attitudes with respect to the accomplishments or not achievements of the program learning outcomes (PLO), the survey questions of the candidates' responses in the research studies must address the following queries: How candidates strongly agree or disagree about the acquired skills and capabilities that led to their successes or failures in learning CHEN 502 and CHEN 407 due to the introduction of CALP for cooperative learning (CL) or peer learning (PL) in project-based learning (PjBL), problem-based learning (PBL), respectively? What attributes of attitudes were very likely or unlikely contributed to the students' successes or failures in learning these two (2) important courses due to the introduction of CALP for PjBL and PBL? How much more or less impact that the introduction of CALP for PjBL and PBL led the students' successes or failures in comparison with the traditional pedagogies for teaching and learning of these courses?

Real-World Complex Engineering Problems

Handling the facilitations and lectures of the fundamental concepts of the crucial core courses of the curriculum for Bachelor of Engineering (B. Eng) in Chemical Engineering like the Process Dynamics and Control (CHEN 502) and Chemical Reaction Engineering (CHEN 407) for more clearer understanding and retentive comprehension are highly challenging. The basic knowledge of these vital courses is really requisite and needed in developing technical skills and capabilities for problem solving skills, tackling real-life encountered problems in the most persuasive, appropriate, and logical pedagogical techniques for the student-centred teaching and learning. It entails creative and critical thinking skills in the development of scientific frameworks for addressing these complex real-world challenges through describing their processes under both steady and unsteady states, finding the dynamics, analysing, and characterizing the transient behaviours, designing controllers, and tuning controllers for the tracking changes in the setpoints and rejecting disturbances, so as to ensure safety and effectiveness of the process operations, monitoring, and control are resolved through an expressive step by step procedures in the case of CHEN 502 (Isah et al. 2022). On the other hand for CHEN 407, sequence of reaction schemes involving multiple competing reactions, multiple consecutive reactions as well as combination of both parallel and series (i.e., complex) reaction systems of several participating species in steady-state flowing, semi-batch or semi-continuous, and ideal batch reactors that are encountered in real-life scenarios, are viewed in their reality, effectively approached and solved in real-time through a fluent step by step algorithmic procedures (Isah and Ameh, 2023).

Traditional versus Non-traditional Pedagogies in Problem Solving Skills

The use of old-fashioned traditional pedagogical methods in teaching and learning were mainly through deductive learning strategies with so many assumptions and generalizations for simplifications in solution techniques for the problem solving skills to the real-world challenges of Process Dynamics and Control as well as the second part of the course synopsis of Chemical Reaction Engineering. These techniques have been utilized since the inception of the Programme for the Bachelor of Engineering (B.Eng) in Chemical Engineering around the globe. It is really quite amazing to discover that several Departments around the globe are still deploying these classical approaches to the aforementioned critical courses, allocating too much of time in the theories and complex mathematics surrounding the descriptions of process models resulting from differential and non-linear algebraic equations based on the nature of the challenges in either CHEN 502 where analysis and characterizations are done using the so called "*The Languages of Process Dynamics and Control*" such as the time domain, Laplace domain, z-domain, frequency domain, and the use of state variables in the Matrix form representation or as the case perhaps in the several scenarios of CHEN 407 reactor design and analysis for optimum product distributions. This is contrary to the effective utilization of resources in devoting more time on the crucial topics like the general concepts for the process modelling, process characterization, controller design, algorithm development for the structures of P-only, I-only, PI, and PID feedback control loops, cascade control loops, and feedforward control loops, and various techniques for controller tuning of vital unit processes, unit operations, auxiliary process equipment, and overall plant-wide controllability as well as looking at the strategies for the distributed control systems (DCS) of modern process plants. In addition, there are several limitations and deficiencies to the ancient analytical graphical techniques employed in the designs, operations, and analysis of reactors ranging from bench to pilot, and pilot to commercial scales for single, multiple competing, multiple consecutive, and complex reaction systems in Chemical Reaction Engineering courses such as CHEN 407. The resulting reaction models into a set of higher order differential equations are impracticable to be solved using these classical methods. A lot of assumptions and generalizations of profiles for some few cases of participating reaction species in steady-state flowing, semi-continuous and ideal batch reactors have to be compromised and made for several species in different cases and scenarios in an attempt to depict and have approximate solutions of the complex real-world challenges. Moreover, there were limitations of both computer software and

hardware with enough required storage spaces and capabilities when the antique solution techniques for the traditional pedagogies were developed but these are still surprisingly found in use around the academia for teaching and learning of these crucial courses!

Contrary, there are a lot of efforts in deploying new and modern innovative pedagogical tools and techniques in the above-mentioned critical courses through the combined strategies of different deductive and inductive teaching/learning approaches such as cooperative learning (CL) or peer learning (PL) in project-based learning (PjBL), and problem-based learning (PBL) for the student-centred learning/teaching (Isah et al. 2022; Isah and Ameh, 2023). In addition to the problem solving skills for the encountered complex real-life challenges that require the applications of taught principles and concepts of these vital courses of ChE curriculum, computer aided learning program (CALP) such as the utilization of specialized commercialized software programs (SCSP) like Control Station®, Loop Pro® Trainer Solution for Academics, Mathematical Software Packages (MSP) such as MATLAB, Polymath® MSP are now utilized in-class activities, assignments, case studies problems related to each of these techniques (Isah et al. 2022; Isah and Ameh, 2023). (Isah et al. 2022; Isah and Ameh, 2023). One of the latest requirements from most of the program learning outcomes (PLO) for the survival and excelling of engineering graduates in the fourth industrial revolution is to acquire the vital skills, capabilities, and attributes for solving complex real-world problems as stated in most of the global engineering bodies such as ABET, Washington Accord, Bologna Process Declaration, and so on (Ali et al., 2021; Phang et al., 2016; Svensson et al., 2016; Kasuba and Ziliukas 2004; Felder and Brent, 2004; Felder and Brent, 2003).

Research Methodology

The concept of computer-aided learning program (CALP) were deployed in the presentations and facilitation of lectures of Process Dynamics and Control (CHEN502) with the aid of Control Station® and Loop Pro® Trainer Solution for Academics. Similarly, specialized commercialized software programs (SCSP) were employed in the the second part, and/or first part of the course synopsis for the old and new revised ChE curriculum of Chemical Reaction Engineering (CHEN 407), and/or Chemical Reaction Engineering II (CHEN 407) using mathematical software packages (MSP) such as MATLAB or SCSP like Polymath® MSP (Isah et al. 2022; Isah and Ameh, 2023). The lectures were conducted in both deductive and inductive ways that supported student-centred active teaching and learning for more than 15 years utilizing the features of cooperative learning (CL) and project-based learning (PBL); and problem-based learning (PjBL) pedagogies in attempt to address the real-life complex challenges in the cases of CHEN502 (Luyben and Luyben, 1997; Ogunnaike and Ray, 1994, Cooper and Dougherty, 2000; Cooper and Dougherty, 2003; Edgar *et al.*, 2006) and CHEN 407 (Levenspiel, 1998; Fogler, 2006; Trambouze, 1959), respectively. A survey questionnaire was used to be administered to the candidates that studied these courses for the purpose of evaluation of the courses, and the design of qualitative research investigations over the years. The course synopsis of the CHEN502 courseware as can be also found in (Isah et al. 2022) included the following skills and capabilities for the course learning outcomes (CLO):

- To study process dynamics and control by first introducing the aims, objectives, and tools for process control strategy and through explaining the definitions of important terminologies used in process dynamics and control,
- To describe the dynamics of process systems and analyse the responses to forcing functions,
- To characterize the process dynamics by finding the process parameters: process gain, process time constants, and process deadtime,
- To study the techniques for linearization and coupling of process systems,
- To learn the instrumentation techniques for flow, level, pressure, temperature, and composition measurements,

- To study different types of controllers and the modes of operation for on/off, proportional (P-Only), proportional/integral (PI), and proportional/integral/derivative (PI&D),
- To study the various types and characteristics of control valves, transmitters, and transducers,
- To design and test a P-Only, PI, PI&D controllers for tracking changes in the setpoint, and rejecting disturbances, respectively
- To explore how controller tuning parameters such as controller gain (K_C) impact on P-Only, PI, PI&D controller performances,
- To study the control schemes and modes for the control of key process variables of the unit operations and unit processes overall process control.

Teammates were used to be formed ranging from eight (8) to eighteen (18) or from seven (7) to nineteen (19), and five (5) to seven (7) team members for the cooperative learning (CL) in project-based learnings (PjBL) for more than 15 years with the assigned responsibilities and stated objectives in order to accomplish the course learning outcomes after the first in-class demonstrations. Four (4) main groups were used to be reformed for tackling their individual unique project-based learning (PjBL) assignments based on four (4) different PjBL case studies. The projects were all about describing the processes mathematically under steady and unsteady states through modelling, finding the process dynamics and characterizing the dynamics into process gain, process time constants, and process deadtime, designing controllers, and determining the controller gain tuning parameters for P-Only, PI, and PI&D controllers, controller testing, and controller tuning for tracking changes in the setpoints and rejecting disturbances. The case studies were for a single loop jacketed reactor with temperature controller, a counter current shell and tube heat exchanger with a temperature controller, a gravity drained non-interacting double tanks processes with a level controller, and distillation column with a composition controller as shown from Figures 1 to 4.

PjBL case study 1: The jacketed reactor is a continuously stirred tank reactor (CSTR) in which the first order irreversible exothermic reaction: $A \rightarrow B$ occurs as shown in Figure 1. Residence time is constant in this perfectly mixed reactor, so the steady state conversion of reactant A from the reactor can be directly inferred from the temperature of the reactor product stream. To control reactor temperature, the vessel is enclosed with a jacket through which a coolant passes. The measured process variable is product exit stream temperature. To maintain temperature at $81.5^\circ\text{C} < T_{\text{exit}} < 99.5^\circ\text{C}$, the controller manipulates the coolant flow rate through the jacket. The disturbance variable is the inlet temperature of coolant flowing through the jacket.

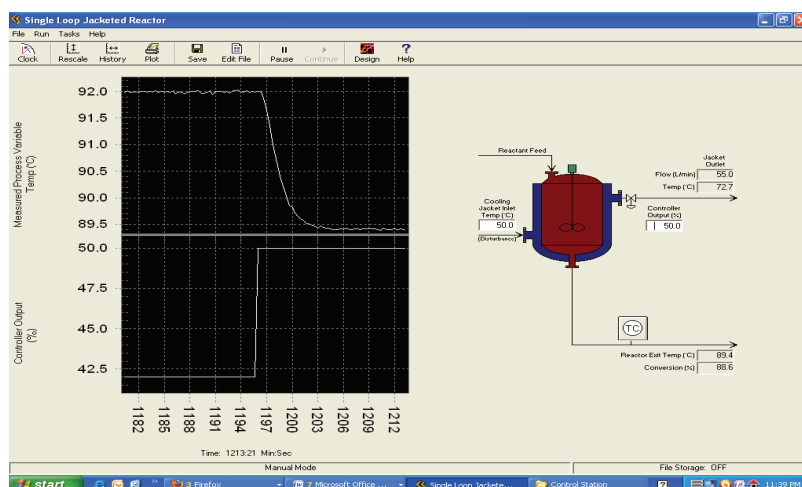


Figure 1: Single Loop Jacketed Reactor with a Temperature Controller

PjBL case study 2: The heat exchanger is a counter current shell and tube, lube oil cooler as shown in Figure 2. The measured process variable is lube oil temperature exiting the exchanger on the tube side. To maintain temperature at $130^{\circ}\text{C} < T_{\text{exit}} < 176^{\circ}\text{C}$, the controller manipulates the flow rate of cooling the controller manipulates the flow rate of cooling liquid on the shell side. Thus, as the controller output (or flow rate of cooling liquid) increases the exit temperature decreases.

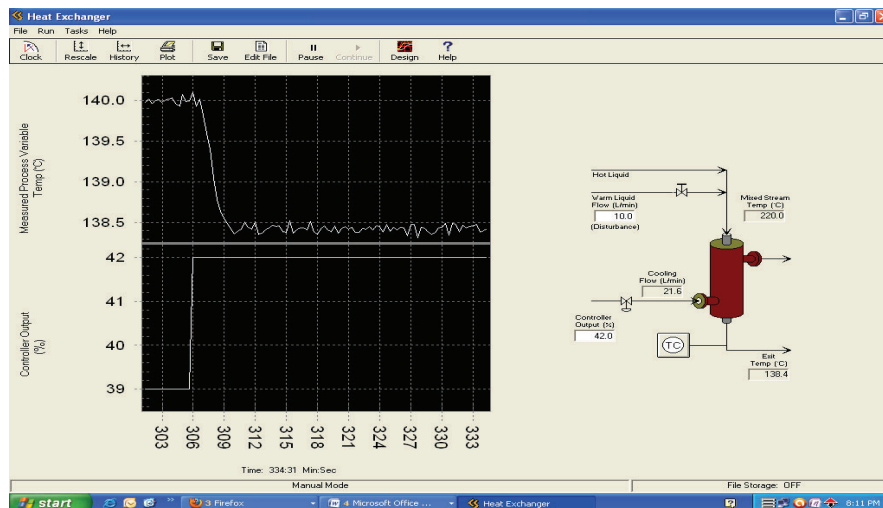


Figure 2: Counter-current Heat Exchanger Process with a Temperature Controller

PjBL case study 3: The gravity drained tanks process is two non-interacting tanks stacked one above the other. Liquid drains freely through a hole in the bottom of each tank as shown in Figure 3. The measured process variable is liquid level in the lower tank. To maintain lower tank level at $1.26\text{ m} < H_{\text{L}} < 7.83\text{ m}$, the controller manipulates the flow rate of liquid entering the top tank. The disturbance variable is a secondary flow out of the lower tank from a positive displacement pump. Thus, the disturbance flow is independent of liquid level except when the tank is empty.

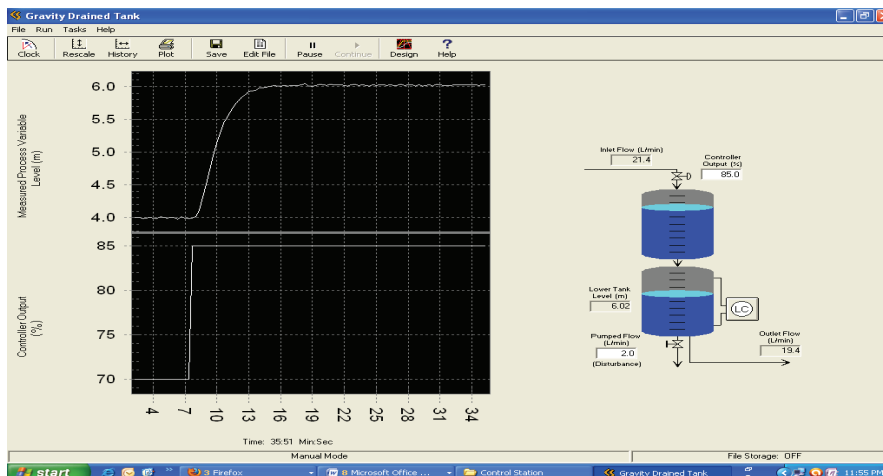


Figure 3: Gravity Drained Tanks Process with a Level Controller

PjBL case study 4: The distillation column as shown in Figure 4 is for binary distillation of benzene and toluene. The objective is to separate toluene from benzene by sending a high percentage of benzene (and thus low percentage of toluene) out the tops stream and a low percentage of benzene (and thus high percentage of toluene) out the bottoms stream. The column dynamic model employs tray-by-tray mass and energy calculations like the one proposed by McCune and Gallier (1973). To maintain top composition of benzene at $75.0\% <$

$y < 98.6\%$, the top controller manipulates the reflux rate to control the top composition. The bottom controller adjusts the rate of steam to the reboiler to control the bottoms composition. Any change in feed rate to the column acts as a disturbance to the process.

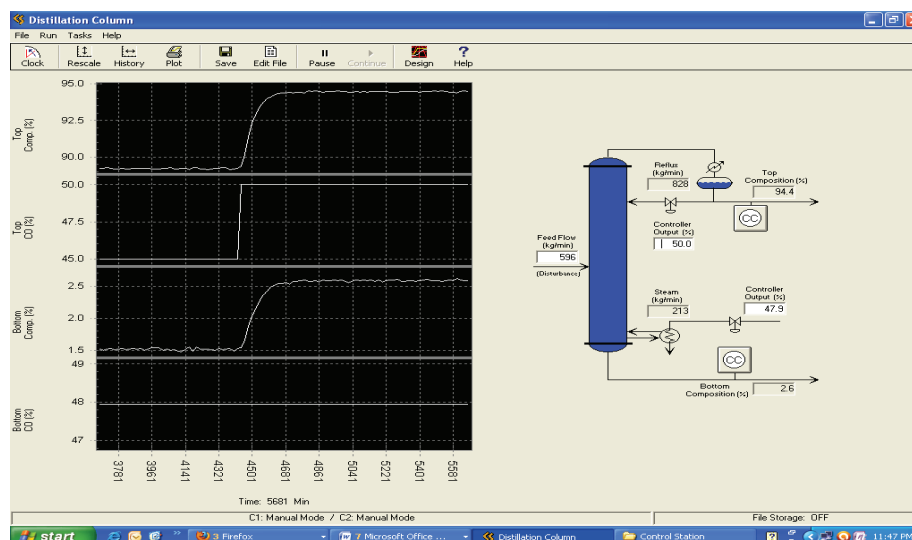


Figure 4: Distillation Column with a Composition Controller

Use the Case Studies Module of Loop-Pro Trainer Solutions to respectively establish your design level of operation (DLO) by changing only the controller output (CO) signal using the specific information provided to you.

- Consider the CO given to you as your CO_{bias} , establish other design level of operations (DLO) parameters, generate, collect and record controller output (CO) to measured process variable (PV) signals when the response is half way (Use Print Screen key to copy it and then take it to MS Word), at the same time storing the dynamic process data to be used for controller design and tuning recipe (name the data as your registration number as for example, U04CE0000.dat and import it into MS Word in tabular form). The data should not be more than 1, 500 data points and should be presented at the end of the report.
- Fit a first order plus dead time (FOPDT) model to the data generated in (a) above to describe the dynamic behaviour (After simulation, use the Print Screen key to copy it and then take it to MS Word).
- Record the FOPDT process model parameters and use them in rules and correlations to complete the controller design and tuning recipe for P-Only, PI, and PID. Also, record the tuning parameters in each case.
- Validate your completed controller designs in c) above and study the tracking changes in setpoint and load disturbance rejections under the three (3) different controller actions. Observe and compare the performance of three (3) controller actions as each attempt to track the changes in set-point and disturbance rejections.
- Explore how the magnitude of tuning parameters in each case of c) above (K_C , and/or τ_I , and/or τ_D) individually impact the controller performance when setpoint tracking is the objective, using averaged moderately aggressive and very aggressive tuning values. Under what conditions the system is likely to be unstable?

Similarly, the topics of the second or first part of the course synopsis for CHEN 407 courseware as shown in Isah and Ameh (2023) included the following capabilities for the course learning outcomes (CLO):

- To study multiple reactions and design for optimum product distributions in an ideal batch and steady-state semi-continuous, and flowing reactors, respectively,

- To examine the influences of temperature and pressure for a single and multiple reactions under adiabatic and non-adiabatic conditions in an ideal batch and steady-state semi-continuous, and flowing reactors, respectively, and
- To study the optimum temperature progression in an ideal batch and steady-state semi-continuous, and flowing reactors, respectively.

Nevertheless, the knowledge, and capabilities learned from the first part of CHEN 407 from the old ChE curriculum, Chemical Reaction Engineering I (CHEN 305) of the new revised ChE curriculum for synopsis of the courses, 7 credit units of Calculus, Differential and Integral Calculus, Differential Equations and Transforms together with 6 credit units of Physical Chemistry and Chemical Engineering Kinetics and Catalysis (CHEN 305) of the old ChE curriculum resulting in a total of 13 credit units were relevant and needed for the retentive comprehension of either the second or the first parts of the course synopsis of the old or the new revised ChE curriculum, respectively. The following skills were the expected CLO of the first part of the course outline for the old ChE curriculum:

- To review the kinetics of homogeneous reactions,
- To study the constant and variable volume ideal batch and steady-state flowing reactor systems, respectively,
- To derive the performance equations for the design, and analysis of single reaction in an ideal batch and steady-state flowing reactor systems, respectively.

A set of open-ended focus complex real-world challenges that possess the characteristics of problem-based learning case studies were considered and tackled for more than 15 years in attempt to address the open-ended problems during the one-month due-date individual assignments in the analysis and design of multiple competing, multiple consecutive, and complex multiple reaction systems for the optimum product distributions of variety of products ranging from petrochemical complexes to commodity, to fine chemical and to specialty chemical, and also to pharmacokinetics analysis of the drug-based products. Algorithms for the resulted coupled sets of ordinary differential equations (ODEs) in the cases of packed bed reactors (PBRs) or assumption of steady-state plug flow reactors (PFRs) or sets of algebraic non-linear equations (ANLEs) in the cases of constant stirred tank reactors (CSTRs) or combination of both flowing reactors for multiple participating species were developed and solved simultaneously in the design and analysis of optimum product distributions for the combination of both multiple parallel and series (i.e., complex) reaction systems (Isah and Ameh, 2023). However, the students were initially taught the skills for critical and creative thinking as well as step-by-step procedures for the development of algorithms for solving complex reaction systems of real-world problems through the combined strategies of deductive and inductive approaches.

Results and Discussion

General Performance in CHEN 502 and CHEN 407 for a Typical Session

A typical academic year, one for each of these two (2) crucial core courses out of many academic sessions, in the curriculum of Bachelor of Engineering in Chemical Engineering, at Ahmadu Bello University Zaria, was selected for the consideration in the research investigations for demonstrations. The overall performance of all candidates in the Introduction to Process Dynamics and Control (CHEN 502) in 2009/2010, and Chemical Reaction Engineering (CHEN 407) in 2010/2011 academic sessions are presented with their cumulative frequencies and analysed, respectively using the mean scores and standard deviations indicators as 104 students, 50.83 marks, and 1.50; and 183 students, 52.49 marks, and 1.36, respectively. The distributions of grade marks for the candidates in CHEN 502 for 2009/2010 session scored 7 A's, 24 B's, 29 C's, 11 D's, 21 E's, and 12 F's, while that of the candidates in CHEN 407 for 2010/2011 sessions scored 15 A's, 38 B's, 67 C's, 22 D's, 28 E's, and 13 F's. The total number of passes in CHEN 502 (A, B, C, D, and E) and failures (F) were 92 and 12.

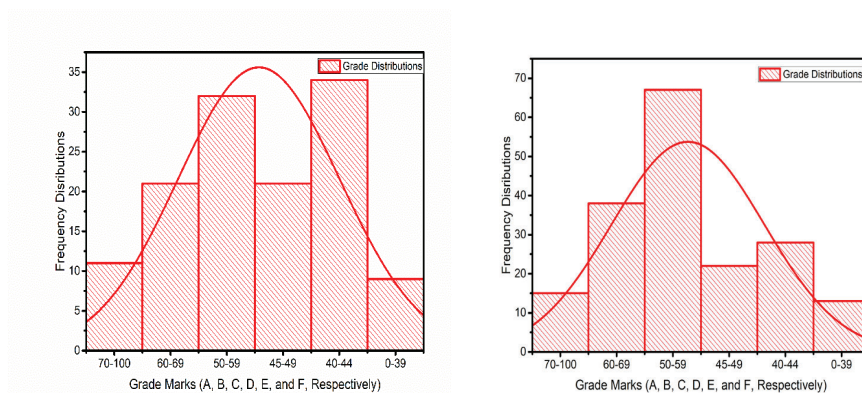


Figure 5: Grade distribution scores in CHEN 502 and CHEN 407 for 2009/2010 and 2010/2011, respectively academic sessions

It can be inferred from the statistical analysis that approximately 68% of the scores are between 49.33 and 52.33 marks, 95% of the scores are between 47.83 and 53.83 marks, and almost all the scores are between 46.33 and 55.33 marks under standard normal curves. On the other course, CHEN 407, the total number of passes (A, B, C, D, and E) and failures (F) were 170 and 13, respectively. It can be inferred from the statistical analysis that approximately 68% of the scores are between 51.13 and 53.85 marks, 95% of the scores are between 49.8 and 55.21 marks, and almost all the scores are between 48.42 and 56.56 marks under standard normal curve as exhibited in Figure 5.

Responses of Research Survey Questionnaire

Several surveys were conducted throughout the periods for handling the lectures, facilitations and administrations of these courses, Introduction to Process Dynamics and Control (CHEN 502) and Chemical Reaction Engineering (CHEN 407) at the Department of Chemical Engineering, Ahmadu Bello University, Zaria for more than 15 years. For this conference paper, surveys of 104, and 183 cohorts of students that were conducted in 2009/2010 and 2010/2011 academic sessions for CHEN 502 and CHEN 407, respectively, were chosen for disclosing the research findings of the survey qualitative investigations. In the survey questionnaires, the students were asked to indicate how strongly they agree or disagree, how most likely or unlikely attained to what led to the attributes for their successes or failures in these two (2) different taught courses CHEN 502 and CHEN 407 at different times. Figures 6 and 7 display the ranking of responses for 104 and 183 candidates in CHEN 502 and CHEN 407, respectively.

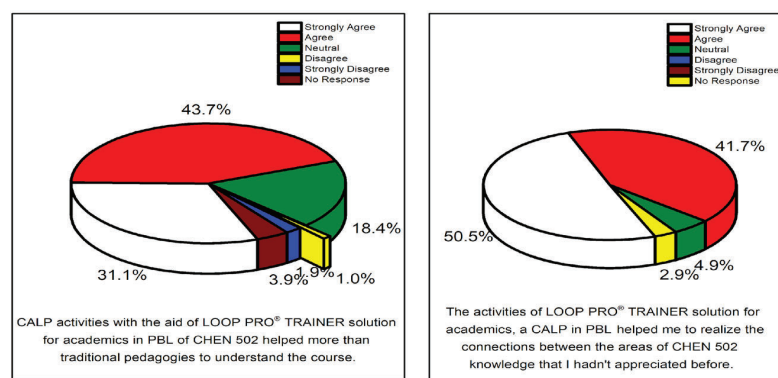


Figure 6: Cooperative and project-based learning (CPjBL) with the aid of computer-aided learning programs (CALPs) in Process Dynamics and Control (CHEN 502)

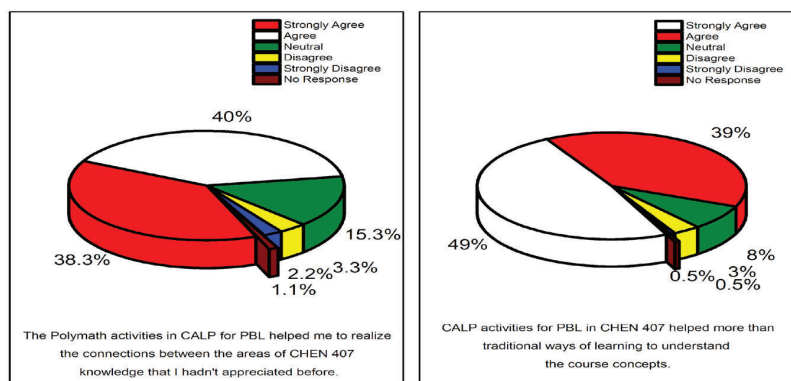


Figure 7: Problem-based learning (PBL) with the aid of computer-aided learning (CALPs) in Chemical Reaction Engineering I (CHEN 407)

The opinions of candidates in computer-aided learning program (CALP) with the aid of Loop Pro® Trainer Solution for Academics for cooperative learning (CL) in project-based learning (PjBL) of CHEN 502 and CALP deploying Polymath® SCSP MSP were assessed and ranked as shown in Figures 6 and 7, respectively. 31.1% and 50.5% strongly agreed and 43.7% and 41.7% agreed that the CALP activities deploying Loop Pro® Trainer Solution for Academics assisted them to realize the connections between the areas of CHEN 502 knowledge that they hadn't appreciated before and CALP activities for PjBL in CHEN 502 helped them than ancient traditional pedagogies in having more clearer understanding and retentive comprehension of the course concepts and ideas, respectively as shown in Figure 6 and 7. However, only 1% and 0% (none of the candidates) disagreed and 1.9% and 0% (none of the students) strongly disagreed with the earlier and later assertions, respectively. In addition, 18.4% and 4.9% were neutral while 3.9% and 2.9% did not respond to both views, respectively.

On the other hand, 38.3% and 49% strongly agreed and 40% and 39% agreed that the Polymath activities in CALP for PBL helped them to realize the connections between the areas of CHEN 407 knowledge that they hadn't appreciated before and CALP activities for PBL in CHEN 407 permitted and facilitated them more than ancient traditional pedagogies in order to have better understanding and retentive comprehension of the taught course concepts and principles as exhibited in Figure 7. However, 3.3% and 3% disagreed and 2.2% and 0.5% strongly disagreed with the former and later assertions, respectively. Moreover, 15.3% and 8% were neutral while 1.1% and 0.5% did not respond to both claims, respectively.

The ranking of the students' responses in the comparison studies between utilization of computer-aided learning programs (CALPs) with the aid of Loop Pro® Trainer Solution for Academics in project-based learning (PjBL) together with that of Polymath® SCSP MSP for problem-based learning (PBL) and ancient traditional learning pedagogies (TLP) in learning CHEN 502 and CHEN 407 as shown in Figures 8 and 9, respectively based on creativity through motivations and enthusiasms and life-long learning for the practice of Engineering Profession.

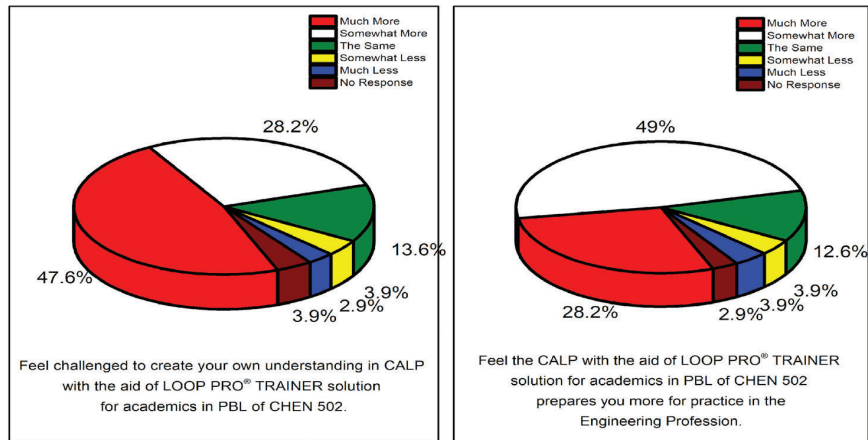


Figure 8: Comparison between CALP for CL in PjBL and traditional learning pedagogies (TLP) in learning CHEN 502 based on creativity and life-long learning for Engineering Practice

It can be observed that 47.6% and 28.2%, and 28.2% and 49% of the candidates were much more, and somewhat more felt that they were challenged to create their own understanding on CALP with the aid of Loop Pro® Trainer Solution for Academics in PjBL and the skills acquired from the course were employed in the process for tackling complex real-world projects in CHEN 502 that prepared them for facing the future challenges of Engineering Profession through that kind of life-long learning, respectively. Nevertheless, 3.9% and 3.9%, and 2.9% and 3.9% of the respondents were somewhat less, and much less in agreements with the earlier and later claims, respectively. Moreover, 13.6% and 12.6% were having the same opinions while 3.9% and 2.9% had no response to both statements, respectively.

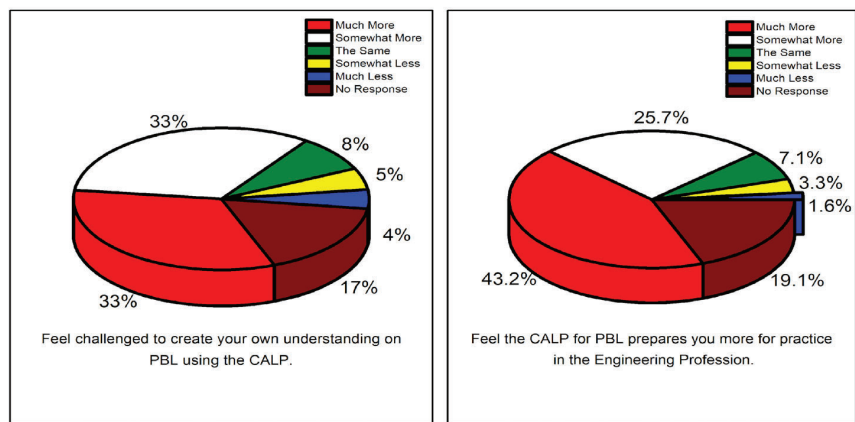


Figure 9: Comparison between CALP for PBL and traditional pedagogies (TLP) in learning CHEN 407 based on creativity and life-long learning for Engineering Practice

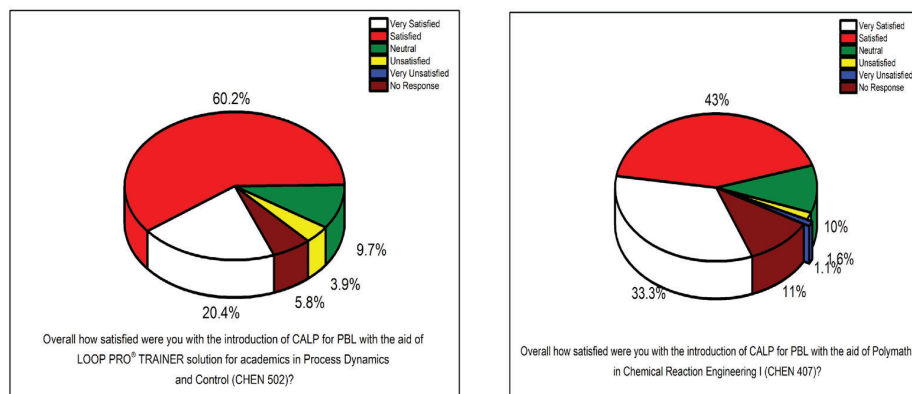


Figure 10: Overall students' satisfaction and dissatisfaction on computer-aided learning programs (CALPs) for cooperative learning (CL) in project-based learning (PjBL) and problem-based learning (PBL) in CHEN 502 and CHEN 407, respectively

In the other course, 33% and 43.2%, and 33% and 25.7% of the respondents were much more, and somewhat more felt that they were challenged to create their own understanding on CALP with the aid of Polymath® SCSP MSP for PBL and the skills acquired from PBL using CALP in the process of addressing complex real-world problems in CHEN 407 that prepared them for future life-long learning and the practice of Engineering Professional challenges, respectively. Nonetheless, 5% and 3.3%, and 4% and 1.6% of the respondents were somewhat less, and much less in agreement with the former and later statements, respectively. Additionally, 8% and 7.1% were having the same opinions whereas 17% and 19.1% had no response to both different views, respectively.

Figure 10 exhibits the ranking of responses for the students on the overall satisfaction and dissatisfaction with the introduction of computer-aided learning programs (CALPs) for cooperative learning (CL) in project-based learning (PjBL) with the aid of Loop Pro® Trainer Solution for Academics and problem-based learning (PBL) using Polymath® SCSP MSP in the processes of learning and addressing complex real-world challenges through the application of taught concepts and principles learnt in CHEN 502 and CHEN 407, respectively. 20.4% and 60.2% of the candidates were very satisfied and satisfied, respectively. However, only 3.9% and 0% (i.e., none) of the candidates were dissatisfied and very dissatisfied with the introduction of CALP with the aid of Loop Pro® Trainer Solution for Academics for CL in PjBL of CHEN 502, respectively. Besides, 9.7% were in a neutral position while 5.8% had no response, respectively. On the other course, 33.3% and 43% of the students were very satisfied and satisfied, respectively with the introduction of CALP utilizing Polymath® SCSP MSP in CHEN 407. Nonetheless, 1.6% and 1.1% of the respondents were unsatisfied, and very unsatisfied with the introduction of CALP for PBL in CHEN 407, respectively. Moreover, 10% were in a neutral position while 11% had no response, respectively.

Conclusions

In conclusion, this research was successful in demonstrating the impact of deployment of computer-aided learning programs (CALPs) with the aids of Loop Pro® Trainer Solution for Academics and Polymath® SCSP MSP for cooperative learning (CL) in project-based learning (PjBL) of the Introduction of Process Dynamics and Control (CHEN502), and problem-based learning (PBL) of Chemical Reaction Engineering (CHEN 407), as a new learning pedagogies in Engineering Education for what led to the candidates' success or failure in some of these vital core courses of the curriculum for the Bachelor of Engineering in Chemical Engineering Programme, with cohorts of 104 and 182 students for 2009/2010 and 2010/2011 sessions, respectively. Survey questionnaires were used to be administered after the completion of each course for the course evaluation and our ongoing qualitative research inquiries for more than

15 years. The main course learning outcomes (CLO) of CHEN 502 were achieved using the case studies for the CL in PjBL in-class work demonstrations, cooperative team work and unique individual project tasks. Likewise, most of the CLOs of CHEN 407 were accomplished for PBL in-class work demonstrations and one-month due-date individual assignments. These results can be seen and observed clearly from the research findings as indicated in the survey responses of the students in the programme. 20.4% and 60.2% of the candidates in CHEN 502; and 33.3% and 43% of the candidates in CHEN 407 were very satisfied and satisfied; respectively, with the introduction of CALPs with the aids of Loop Pro® Trainer Solution for Academics and Polymath® SCSP MSP in the process of learning and tackling complex real-life challenges, respectively. Nonetheless, only 3.9% and 0% (none), 1.6% and 1.1% of the candidates in the cases of CHEN 502 and CHEN 407 were respectively dissatisfied and very dissatisfied. Moreover, 9.7% and 5.8%; 10% and 11% were having neutral positions and no responses, respectively.

References

- Ali, M. Y., Ya'akub, S. R., Singh, R., Al Hazza, M. H. F., & Adesta, E. Y. (2021). Quality assurance in engineering education: accreditation and its global influence. In *Proceedings of the 11th Annual International Conference on Industrial Engineering and Operations Management*. <http://ieomsociety.org/singapore2021/papers/1305>
- Cooper D. J., Dougherty D., & Rice, R. (2003). Building Multivariable Process Control Intuition Using Control Station®. *Chemical Engineering Education*, 37(2), 100-105. <https://journals.flvc.org/cee/issue/view/5661>
- Cooper D., & Dougherty D. (2000). A training simulator for computer-aided process control education. *Chemical Engineering Education*, 34(3), 252-257. <https://journals.flvc.org/cee/article/download/123064/122109>
- Edgar T. F., Ogunnaike B. A., Downs J. J., Muske K. R., & Bequette B. W. (2006). Renovating the undergraduate process control course. *Comp. & chemical engineering*, 30(10-12), 1749-1762. <https://doi.org/10.1016/j.compchemeng.2006.05.012>.
- Felder R.M., & Brent R. (2016). *Teaching and learning STEM: A practical guide*. John Wiley & Sons
- Felder, R.M., and Brent, R. (2004). The ABCs of engineering education: ABET, Bloom's taxonomy, cooperative learning, and so on. In *Proceedings of the 2004 American society for engineering education annual conference & exposition* (Vol. 1). American Society for Engineering Education.
- Felder, R.M., and Brent, R. (2003). Designing and Teaching Courses to Satisfy the ABET Engineering Criteria. *Journal of Engineering Education*. 92 (1), 7-25. <https://doi.org/10.1002/j.21689830.2003.tb00734.x>.
- Fogler, H.S. (2006). *Elements of Chemical Reaction Engineering*, Pearson Education, Inc. New Jersey, Prentice Hall.
- Isah, U.A., Adamu, S., and Olawale, A.S. (2022). Integrated Computer-Aided Learning Program in Process Dynamics and Control–A Senior Course in B. Eng Chemical Engineering Degree for Cooperative and Project-Based Learning Implementation, *J. Appl. Sci. Envir. Stud.* 2022, 5(4), pp. 231-252. <https://doi.org/10.48393/IMIST.PRSM/jases-v5i4.54518>.
- Isah, U.A., and Ameh, A.O. (2023). Integrated Computer-Aided Learning Program in Chemical Reaction Engineering I–A Senior Course in B. Eng Chemical Engineering Degree for Problem-Based Learning Implementation, *J. Appl. Sci. Envir. Stud.* 2023, 6(1) pp.1-19. <https://doi.org/10.48393/IMIST.PRSM/jases-v6i1.55570>.
- Kasuba, R., & Ziliukas, P. (2004). A comparative review of two major international accrediting consortia for engineering education: the Washington Accord and the Bologna Process. *World Transactions on Engineering and Technology Education*, 3(1), 71-74. [http://www.wiete.com.au/journals/WTE&TE/Pages/Vol.3,%20No.1%20\(2004\)/15_Kasuba57](http://www.wiete.com.au/journals/WTE&TE/Pages/Vol.3,%20No.1%20(2004)/15_Kasuba57).
- Levenspiel, O. (1998). *Chemical Reaction Engineering*. New York: John Wiley & Sons.
- Luyben, M. L., & Luyben, W. L. (1997). *Essentials of process control*. New York: McGraw-Hill Companies, Inc.
- McCune, L. C., & Gallier, P. W. (1973). Digital Simulation-Tool for Analysis and Design of Distillation Controls. *ISA Transactions*, 12(3), 193-207.
- Ogunnaike, B. A., & Ray, W. H. (1994). *Process dynamics, modelling, and control*. New York: Oxford University Press, Inc.
- Phang, F. A., Anuar, A. N., Aziz, A. A., Hassan, S. A. H. S., Yusof, K. M., Khamis, N., ... & Ahmad, Y. (2016, August). What are complex engineering problems in the eyes of engineering lecturers? In *The 6th Regional Conference on Engineering Education* (pp. 9-10).
- Prince, M., & Felder, R. (2007). The many faces of inductive teaching and learning. *Journal of college science teaching*, 36(5),
- Prince, M.J., and Felder, R.M. (2006). Inductive teaching and learning methods: Definitions, comparisons, and research bases. *Journal of engineering*, 95(2), 123-138. <https://doi.org/10.1002/j.2168-9830.2006.tb00884.x>.
- Rugarcia, A., Felder, R.M., Stice, J.E., and Woods, D.R. (2000). The Future of Engineering Education: I. A Vision for a New Century. *Chem. Engr. Education, in the Press*. <https://journals.flvc.org/cee/article/view/123095>.
- Svrcek, W. Y., Mahoney, D. P., & Young, B. R. (2014). *A real-time approach to process control*. John Wiley & Sons.
- Trambouze, P. J., and Piret, E. L. (1959). Continuous stirred tank reactors: Designs for maximum conversions of raw material to desired product. Homogeneous reactions. *AIChE Journal*, 5(3), 384-390. <https://aiche.onlinelibrary.wiley.com/doi/abs/10.1002/aic.690050325>.

Svensson, C., Antony, J., Ba-Essa, M., Bakhsh, M., & Albliwi, S. (2015). A Lean Six Sigma program in higher education. *International Journal of Quality & Reliability Management*, 32(9), 951-969. <https://doi.org/doi/10.1108/IJQRM-09-2014-0141>.

Acknowledgments

The author Umar Isah Abubakar, PhD thanks Allah SWT for everything. He gratefully acknowledges the financial support from Ahmadu Bello University (ABU) Zaria for the procurement of ten (10) licences of the floating network of Loop Pro® Trainer Solution for Academics from Control Station, Inc. in 2010, and renewing the licenses in 2011. He would like to show his appreciation to Prof. Douglass J. Cooper, the Founder and CTO of Control Station, Inc., Department of Chemical, Material, and Biomolecular Engineering, University of Connecticut, USA for the teaching collaborations. He would like to also show his appreciations to Prof. H. Scott Fogler, Ame and Catherine Professor of Chemical Engineering, The University of Michigan, Ann Arbor, USA, Prof. Octave Levenspiel, Department of Chemical Engineering, Oregon State University, USA, Prof. Michael Cutlip, Chemical, Material, and Biomolecular Engineering Department, University of Connecticut, USA, and Prof. Robin Smith, Centre for Process Integration, School of Chemical Engineering and Analytical Science, University of Manchester, UK, for the case study problems related to the PBL exercises in their texts, *Elements of Chemical Reaction Engineering*, and *Chemical Reaction Engineering*, the opportunity to acquire an Unlimited Academic License of Polymath®, and clarification of misconceptions about the concept of selectivity from broader perspectives of Process Engineering. The author acknowledges the supports from Prof. Nuhu Mu'azu Dalhatu, Department of Environmental Engineering, Imam AbdurRahman University, Dammam, Saudi Arabia, and Dr. Hassan Funsho Akande, Department of Chemical Engineering, Kaduna Polytechnic, Kaduna to the success of this work. Likewise, he would like to show his appreciations to some of the staff of Ahmadu Bello University, Zaria, Engr Ibrahim Ladan, Network Infrastructure and Services (NIS) Unit, Iya Abubakar Institute of Information and Communication Technology (IAIICT) for the technical supports, and Malam Musa Abdullahi Rabbah for collating the students' responses of the research survey questionnaires and documenting them.

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