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Maximizing Students Performance through Inclusive Teaching in Chemical Engineering Education

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ABSTRACT

The diversity nature of Nigeria also reflects in the chemical engineering students' matrix in the tertiary institutions across the nation, and there is growing yearnings for a paradigm shift in the teaching methods. A survey conducted at the Faculty of Engineering, University of Port Harcourt, Nigeria in 2021, revealed that there is a wide gap among the various generations Baby Boomer, Baby Bust (generation X), Millennials (generation Y) and i Gen (generation Z) of lecturers in relation to students. As a result of this gap, and other barriers such as social background, imbalance in the curriculum, and disability which are speculated to affect adversely the academic performance of the students, the current work examines the use of inclusive teaching approach to change the narrative. The performance of students in a Process Optimization course was assessed over ten different classes (students set) from 2007 to 2016. The results show that prior to the improvement of the teaching method to include the use of technologies such as Piazza, Google form, and Jot form, the performance of the students was highest in the 2012 set as the number of students that passed exceeded those that failed by 12. Upon the introduction of technology in the 2015 set, the performance of the students increased greatly with the highest recorded in the 2015 set with the number of students that passed the course exceeding those that failed by 39. Thus, inclusive teaching can help to improve the students' academic performance.

Keywords: Inclusive; Stereotype Threat; Exclusive; Students-Centered; Diversity

Introduction

Nigeria is a multinational state with over 250 ethnic groups speaking 500 dialects with Igbo, Hausa and Yoruba as the three most predominant ethnic groups. Explicitly, Nigeria is a country with great diversity. In this regard, diversity is defined as persons with peculiar traits such as "communication skills, culture, marital status, ability to attend, learning abilities, intelligence, interests, (cognitive abilities), values, social skills, family support, learning styles, age, socioeconomic status, religious beliefs, sexual orientation, ethnicity, physical abilities, sensory abilities, race and gender" [1]. This diversity is reflected in the composition of over 500,000 students admitted annually into the Nigerian tertiary institution, including chemical engineering students. Usually, Nigerian students are taught by most lecturers using the traditional teacher-centered teaching methods. That is, the teachers play a dominant role in the learning process such as providing information; assessing the students; setting the intended learning outcomes to be achieved by the students; determining the pace of the Edeh and Kuye (2023) lecture; asking all the question; and presenting class activities to be carried out by the students within a specific period of time. With this arrangement, the students are seen as passive learners. The implication of which is that the students become more competitive and individualist, since they are given less opportunity to interact with each other and to think [2]. These negative impacts can be resolved by using the students-centered teaching approach which encourages the students to be in control of their own learning while the teacher facilitates the learning process. This approach involves inclusive teaching which is also known as Universal Instructional Design or Universal Design of Instruction or Universal Design for Learning (UDL) [3]. Inclusive teaching requires university lecturers to respond to student diversity, regarded as mutual enrichment [4,5] and to acknowledge that all students are

able to learn [6]. Thus, the emphasis should be on relevant changes to be implemented in educational institutions, in order to offer an education of the highest possible quality and excellence. Moriña (2020) [7] research indicated that lecturers that are committed to educational inclusion at university prefer to use active methodologies that focus on students' needs and interests.

Studies by Lavy (2017) and Seatter and Ceulemans (2017) [8,9] showed that peer tutoring and cooperative learning have proven to be effective strategies to make inclusion in Higher Education a reality. Other studies highlighted the need to develop practices based on the UDL [10], so that students are respected in their ways of feeling, thinking and acting by using teaching processes such as research projects, problem-based learning and flipped classrooms [11]. Bortolini, et al. [12], however, highlighted the need to train lecturers on the conceptual and methodological foundation in educational inclusion to deal with diversity at university. Fernández-Fernández, et al. [13] suggested training workshops for university lecturers to raised awareness on the relevance of attitudinal aspects (empathy, understanding, tolerance, active listening) to make inclusion in Higher Education possible. Thus, inclusion in Higher Education requires the presence of a coherent teaching staff, faithful to their principles and beliefs, who fully trust what they do and in view of the events must keep doing [14]. Lecturers should promote values and design conditions that lead students to access knowledge through experience and shared learning [15]. The implication of this shift is that the role of the lecturer changes from that of information presenter to that of a learning coach, guider and facilitator [16,17]. This allows the lecturer to spend additional time working one-on-one or in small groups, which is an effective way to meet the needs of students with learning difficulties. Inclusive teaching components are shown in Figure 1. It involves embracing a reflective practice and a welcoming attitude, as well as varying teaching methods to offer an engaging, challenging and essential learning activities in an environment characteristic of cognitive emotionally and physically safe, and devoid of barrier [18].

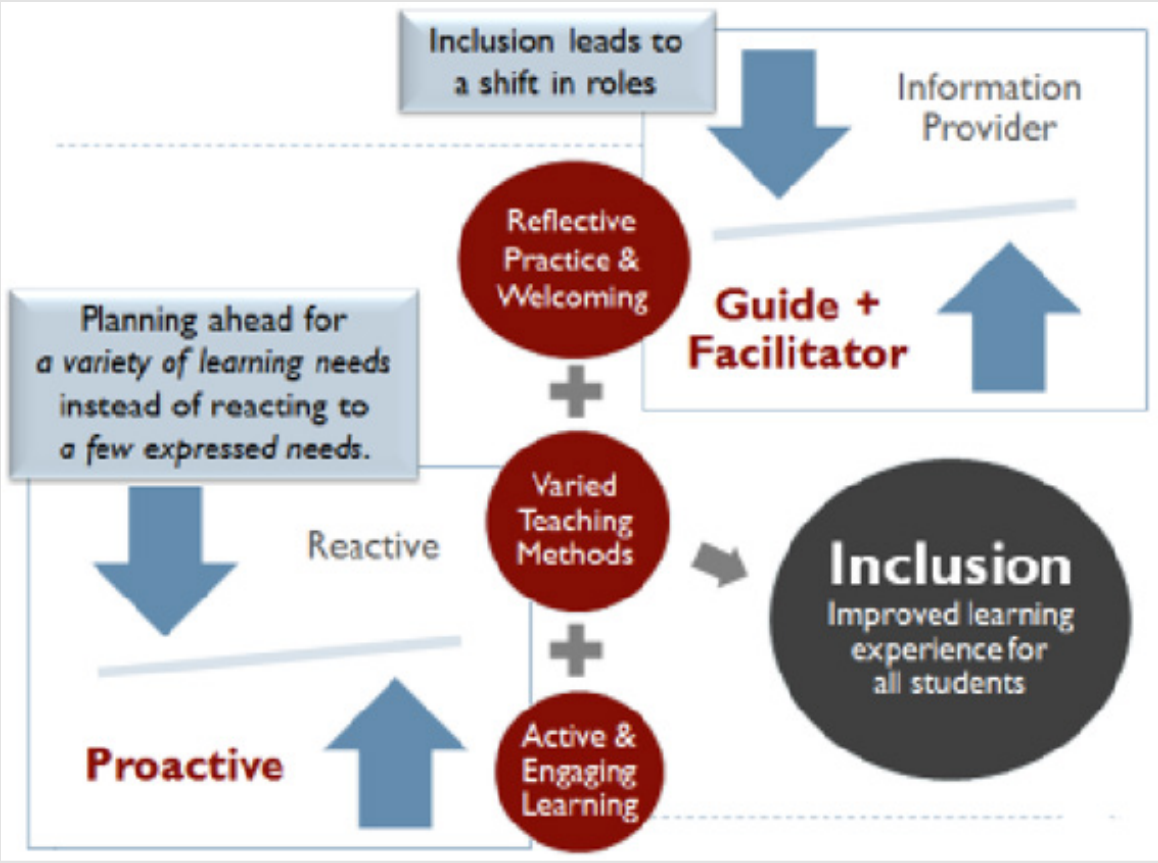

Figure 1: Inclusive teaching new paradigm (Source: Beaudoin, 2013).

Inclusive teaching begins by asking the following questions:

1. What is the background of the students?
2. Do the students have any learning needs?
3. Why participation imbalance exists among the students?
4. Why do some students learn faster than others?
5. How cultural orientation might influence interaction with students?
6. How might the identities, ideologies, and backgrounds of the student's impact on their level of engagement?
7. How redesigning of the course and change of teaching method encourage participation by all the students?

The current work reviews how students who may be marginalized as a result of age, gender, ethnicity, social class, socio-economic disadvantage, disaffection, truancy, religion, persistent misbehavior, sexuality, disabilities, or poor attainment could be actively engaged in the learning process using inclusive teaching in order to widen the horizon of their learning experience and enable them to perform optimally. Inclusive learning is discussed from the perspective of the changing generational landscape of the teaching environment, teaching methods and learning styles. A practical application of inclusive teaching based on Process Optimization being taught by the authors at the University of Port Harcourt, Nigeria over ten different sets of students in ten years was demonstrated.

Method

The methodology adopted in this study is secondary data analysis. The paper is descriptive and based on thorough analysis of relevant articles. A practical application of inclusive teaching in chemical engineering was demonstrated.

Results

The results are the narrative discussions and recommendations that are organized into three thematic areas, followed by a demonstration of the impact of inclusive teaching in chemical engineering.

Generational Changing Landscapes of Teaching Environment

Generations, as used in this work, refer to classification and investigation of groups of people born within a 15- to 20-year span. It is believed that individuals born in a given generation share similar characteristics and attitudes across various social domains. Although the labels and age cutoffs for different generations vary among researchers, the Pew Research Center classification [19,20] is given in Table 1. The characteristics of different generations are also summarized in Table 1. The Baby Boomer Generation is not as technologically savvy as the other Generations, rather they define themselves by their jobs. Baby Boomer Generation are hard-working and focused; Generations X and Y balances work with life while Generation Z are pragmatic and financially focused. The different Generations are independent with the level of independence decreases as the generations get younger. The generation distribution for students and lecturers in the Faculty of Engineering, University of Port Harcourt, Port Harcourt, Nigeria is shown in Figure 2. Figure 2 indicates that the majority of the students belong to generation z. Thus, it is expected that these students want directness over subtlety, are always hurried but know what they want and more likely to judge someone for what you are rather than for who you are. They are surfers and scanners, not readers and digesters. They want a solid knowledge base and real-world applications; clear and organized presentation of materials; to be stimulated, active and participatory; and their lecturers to be enthusiastic, helpful and engaged. The lecturers are mixed, comprising three generations. The older lecturers belong to the healthiest and wealthiest of generations to date. They are hard-working, passionate and believe in hierarchy but may find it difficult to adapt to more flexible arrangements. The younger lecturers are entrepreneurial, value work-life balance, ambitious but know they must keep learning to be marketable and expect instant gratification. Clearly, there is a generation gap between the lecturers and students; the ages of incoming students are decreasing while the lecturers are aging. The challenge before the lecturers is therefore to be effective in teaching and to make teaching and learning relevant to the students' expectations. Some of the available techniques for overcoming this challenge in an inclusive manner are discussed in Section 4.

Table 1: Name, age cutoffs and characteristics of different generations.

Generation Name	Births Start	Births End	Youngest Age*	Oldest Age*	Characteristics
Baby Boomer Generation	1946	1964	57	75	Hard-working and focused · Competitive · Value relationships · Are self-sufficient. · Independent · Pursue excellence and quality · Equate authority with experience. · Pride themselves on decision-making skills. · Define themselves by their jobs
Generation X (Baby Bust)	1965	1980	41	56	· "Latchkey" kids – both parents working · Entrepreneurial, value work-life balance, independent · Technologically savvy · Ambitious, self-starters · Expect instant gratification, immediate feedback · Know they must keep learning to be marketable
Millennials or Generation Y	1981	1996	25	40	· Value work-life balance · Overindulged, overprotected, self-absorbed · Technologically savvy · Self-confident · Ambitious with high expectations · Want to know process, rules, how to get ahead · Expect to start at the top · Want constant and immediate feedback · Move quickly from one thing to another · Not as independent as Gen X (parental back-up)
iGen / Gen Z	1997	2012	9	24	· First "digital natives" – Its all about technology · Pragmatic and Financially focused · Shrewd consumers and Entrepreneurial · Competitive · Diversity is their norm - more likely to judge someone for what you are, rather than for who you are · Independent but wants to be heard

Note: *age if still alive in 2021.

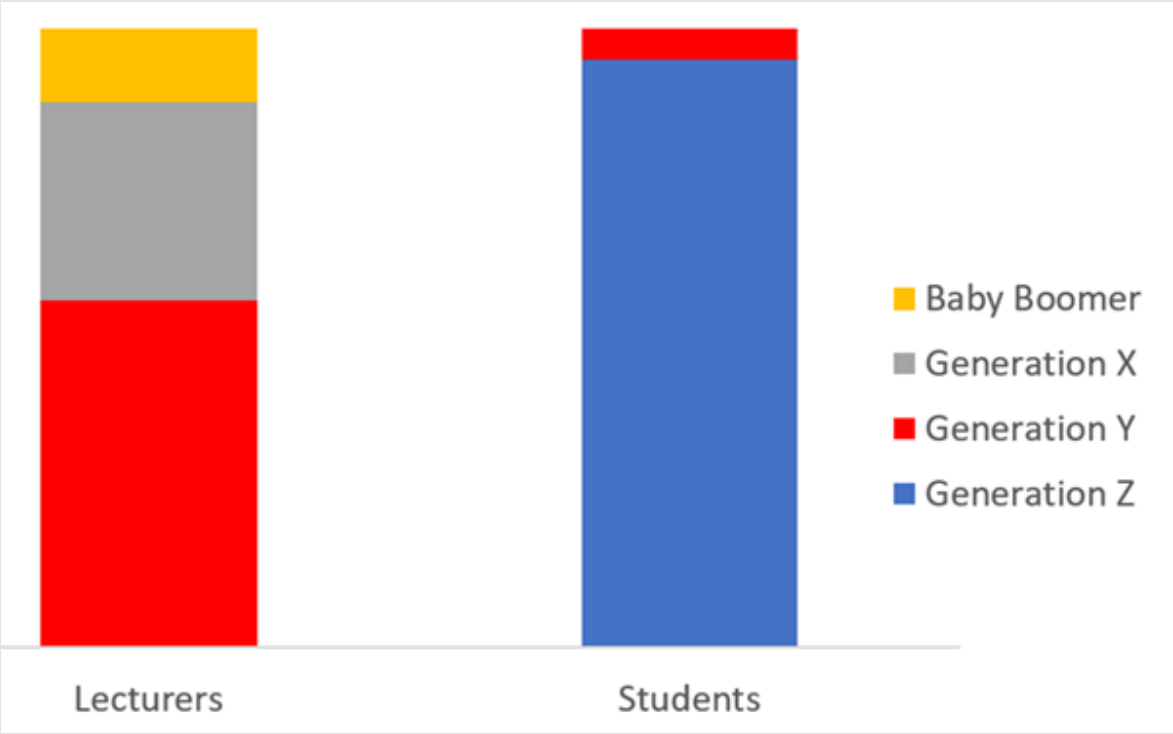

Figure 2: Generational distribution of students and lecturers.

Factors Affecting Inclusive Teaching

Social Background: This is reflected on the disparity in the academic performance between the students from low-income and high-income backgrounds [21]. The students from the later background tend to perform better probably because they had better academic exposure engendering full participation in class activities prior to being enrolled in the university [22].

Imbalance in the Curriculum: Globally, the curriculum seems to favour Western, white, male, middle-class perspectives which is usually evident on the curriculum content and reading lists. There is need to review the reading lists with the students and to include more reading materials and perspectives from marginalized scholars [23].

Disability and the Social Model: According to Oliver (2004) [24], two models of disability exist, and they include medical and social models, respectively. Medical models deal on impairments and how they can be fixed to enable the individual to perform their functions effectively and fit well in the society. Conversely, the social model focuses on how the structure of society marginalizes and imposes restrictions on people with disabilities preventing them from full participation. It is therefore paramount to reduce the impact of functional limitations and to eliminate the barriers due to disability through inclusiveness to ensure fairness and equity in teaching and assessment, and by providing accessible learning environment [4]. This can also be achieved by changing the way staff and institution perceives marginalized students or colleagues.

Unfortunately, most students with non-visible disabilities find it difficult to disclose such to their Lecturers, probably because of fear of being discriminated. There is no doubt that keeping this secret would work to their disadvantage, and as a result of that Lecturers are encouraged to create an atmosphere of trust and positive class climate to enable students with specific needs to open up. Common non-visible disabilities among students include learning disability, an attention deficit disorder, or a mental health issue. Students with mental health challenge could be confronted with such difficulties as handling time pressure, maintaining attention to task, interacting with others, being uncomfortable with changes, keeping energy level up, approaching authority figures, processing information, reading, coping with stress, etc. [25]. These limitations could have a negative impact on a student trying to understand the course content, structure their learning, engage and participate in class, write exam or assignment, etc. To help such students, Lecturers are required to vary their teaching methods, provide enabling environment and give opportunities for all the students to succeed and reach their full potential without reducing the academic standards [18].

Strategies and Tools for Inclusive Teaching

Numerous works have been carried out on the strategies and tools for inclusive teaching as contained in the literature, but the following key strategies are considered in this work:

Creating an Inclusive Curriculum: Inclusive curricula design involves adjustment in the contents, teaching style and assessment geared towards ensuring fairness and equity [23]. This can be achieved by collaborating with students and community members depending on the course. Inclusiveness can be incorporated into the course content by widening the reading lists to include textbooks written by authors from diverse cultural background including Nigeria, and presenting examples in view of various ethnic and racial perspectives. To integrate inclusive teaching in a course, lecturers/educators are required to ask themselves the following questions relating to goals, learning needs and teaching methods [26]:

1. What are students expected to know, do, or value at the completion of this course?
2. What are the core outcome goals for all students?
3. How will the course standards be communicated to students?
4. How do I prepare students to meet the assignment expectations?
5. How do my strategies for assessment reflect key learning goals?
6. How do I factor in individual differences?
7. What would you like me to know about you as a learner to help make this course a successful experience?"
8. How is my teaching method affecting your learning and suggest how I could teach you better? This could be done through an anonymous survey at mid-term and end of the term.

Table 2: Comparison of Teacher- and Learner- Centred Teaching Methods.

Teacher-Centred	Learner-centred
Focus is on instructor; students are passive	Focus is on students; students are actively engaged
Instructor transmits knowledge to students Instructor talks; students listen and take notes	Students construct knowledge by gathering, synthesizing and integrating information while developing skills like inquiry, problem solving, communication, and critical thinking
Lecture is the main method of teaching	Instructor is a coach, model and mentor who lectures sparingly
Instructor makes decisions; sets learning objectives, assignments and assessment criteria	Students are involved in decision-making, participate in developing learning objectives, defining assignments and assessment criteria
Knowledge acquisition is gained apart from its use in real life	Learning to use knowledge effectively, collaborating with others to address real life situations and problems
Students work alone	Students work in pairs, groups, or alone
Instructor monitors and corrects students	Instructor provides feedback/encouragement/correction
Instructor answers students' questions	Students answer each other's questions, using instructor as an information resource. Focus on asking better questions
Instructor evaluates student learning Assessment is used to monitor learning	Students engage in self-evaluation and peer-evaluation in addition to receiving teacher-evaluation. Assessment promotes learning. Students provide teacher with feedback on facilitation process

Active Learning and Varying Teaching Methods: Available teaching methods can be classified broadly into two groups namely: teacher-centered and learner-centered (see Table 2). The teacher-centered approach is often called the traditional teaching method. The learner-centered approach emphasizes is on the person doing the learning (Weimer, 2002). Other similar terms to learner-centered approach include Learner-Centered Teaching, Student-Centered Learning, Collaborative Learning, Active Learning, Team-based Learning, Project-based Learning and Problem-based Learning.

The goals of Student-Centered Learning are to:

1. Offer a better way of educating.
2. Improve how students learn and teachers teach.
3. Actively engage students in learning.
4. Share responsibility with students for learning.
5. Move toward student guided instruction.
6. Prepare learners with 21st century skills.
7. Incorporate technology in learning.
8. Grow lifelong learners.

Active learning is a student-centered learning approach in which Lecturers/educators facilitate students' engagement and encourage them to take responsibility of their own learning. Some characteristics of students-centered learning method are presented in Figure 3 and facilitators are encouraged to design their courses in a manner that promotes varieties of active learning activities to engage the students

while considering diversity. These activities could be by presentation, mini-lecture, case study, scenario, question period, mini-project, debate, asking simple questions, giving opportunities for students to answer questions, encouraging students yet to answer questions to do so, and getting students involved by putting them in a small group [27,3]. For instance, in Chemical Engineering Laboratory, students can be encouraged to write lab reports in a group or as individuals. The facilitators can also deliver the course content in a variety of ways that encourage the full participation of all the students in learning. This could be for instance, verbal, visual, written, video, audio files and graphs. The students can be supported and guided in their learning by using technology like course management system (e.g., Blackboard Learn); problem solving software like Piazza; offering office hours; interactions via email, zoom, Skype, etc; assessing their learning needs and making recommendations (e.g. study aids, mentoring, writing assistance, enrollment on courses that sharpen the transferable skills of the students (communication skills, time management, computing, etc.) [3].

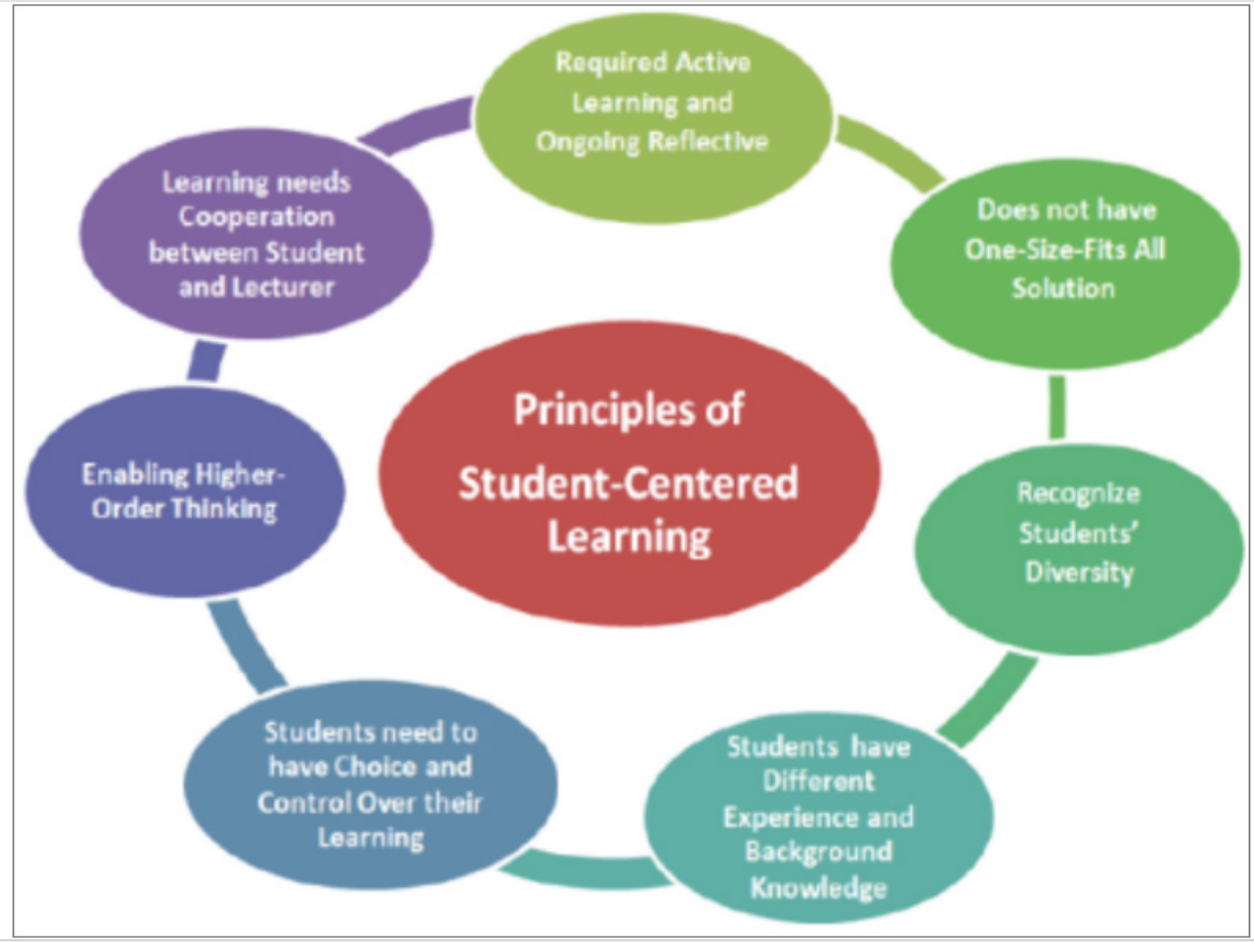

Figure 3: Principles of Student-Centered Learning (Abdullah, et al., 2013).

Designing Inclusive Assessment: Inclusive assessment involves integrating diversity in assessment design by removing all the barriers hindering students from learning and providing them the opportunity to demonstrate their knowledge and skills in a manner that enables them to succeed. The students can be involved in developing the assessment tasks, constructing assessment criteria and making decisions regarding their works thereby helping them to understand the assessment standards, monitor and develop their work [23]. They can be allowed to select assessment type from a range of options in their domain of interest, strength, learning style, needs, time constraints, personal or employment commitments [28]. For instance, some students may prefer to write examination probably because, they have developed resistance to exam pressure and stress, while others might have phobia and as such would

opt for an alternative assessment method. Also, students could be provided with varieties of question types such as multiple choice, open-ended essays, compare-and-contrast, and practical applications of theoretical principles. However, in as such as all the students irrespective of their situations are to be carried along, there is need to encourage them to solve challenging questions, even when they fail, failure is a component of the learning process. Challenge with respect to inclusive teaching enables the students to explore new areas and provides them with requisite experience to succeed as chemical engineers. They could always be given necessary support peradventure they get stuck, and encouraged try harder [29,30]. Inclusive assessment can also be achieved by using introductory or formative modules to help students to understand how to think in the discipline and expose to various assessment methods available [31].

The following questions can help the facilitator in designing inclusive assessment [1]:

1. "Are the instructions on this assessment easy for students to understand?
2. Is the layout of the assessment easy to navigate?
3. Are items formatted consistently throughout the assessment?
4. Is the language I am using in the assessment appropriate for the students in my classroom? Will students understand the vocabulary associated with information not directly related to the coursework?
5. Is the print large and legible enough for all students to read? Are diagrams clear and consistent with text?
6. Can the assessment be taken in a variety of formats (e.g. paper, computer-based)?
7. Can a potential allowable accommodation for a student be used on this assessment without changing the constructs of what I am testing?".

Providing Accessible Learning Materials: These may be written or online materials in PDF, MS word, PowerPoint and Excel. Learning materials should be designed in a manner that encourages easy reading, understanding and accessibility (for instance "readable with a word-to-voice program; include Alternate text and screened via the Accessibility Checker feature from the Microsoft Office Suite"). Providing the materials in advance increases readability and enables the students to prepare, participate fully and enjoy total autonomy of their own learning. However, clear guidance should be provided to the students to direct on how the materials should be used, otherwise it could just be addition to their workload.

Creating Inclusive Learning Environment: An inclusive environment should be bias free and characterized by a positive class climate where all the students are welcomed and treated equally. Some of the ways by which an inclusive learning environment can be fostered include:

1. Caring for the students by empowering them to be successful in both academic and personal endeavors [32]. The performance of the students can improve if they believe that the instructor cares about them and have confidence that they can perform better. This helps to reduce apprehension in class, increase motivation and possibility of working with the instructor's feedback, ensure positive attitude towards the course, and improve independent learning.
2. Respecting the students by appreciating their diversity which may be predicated on culture, gender, socioeconomic status, ability, sexual preference, dialect, race, ethnicity, religion and age (Simmons, 2006).
3. Developing relationships with the students by empowering them to be involved in the learning process, mentoring them, being able to remember and pronounce their names correctly, and identify their passion and motivate them [33,34].
4. Helping students to develop their self-esteem by offering constructive feedback and encouraging them to share their opinion [35]. Also, success has a way of sustaining students' interest and motivation to learn, and to believe in oneself. The students should be praised and given positive feedback in view of succeeding in the subject matter, and not being too critical when they provide incorrect answers. Appreciation and rewards are also required to facilitate fun and enjoyment in view of success. With this, the students would desire to do more and to be successful [26].
5. Empowering the students to maintain a good self-image. This has to do with the perception of one's abilities, appearance, and personality. Chemical engineering is seen as being challenging by most students as it requires a firm foundation of mathematics, basic sciences, and engineering studies. Bearing this in mind, some students struggle, leading to negative self-image while others who have the capability to grasp new idea and procedures speedily excel. This problem can be solved using inclusive teaching by telling all the students in the class that they can excel in chemical engineering; understand chemical engineering; and that chemical engineering is for them. The Lecturer needs to treat all the student with respect [26].
6. Catering for the need of every student by applying the principle of differentiation. This involves being able to cater for the needs of each student in the class. For instance, students who are struggling and those excelling, inattentive students, students who missed the previous classes, and those disabled. To achieve this, the Lecturer must develop tasks that could be easily carried out by the majority of the students and could reserve very complicated ones as supplementary to exceptional students.

Handouts of the lectures to be delivered could be given to the students with sight problems, and inattentive students could be made to sit on the front seats in the classroom [26].

7. Minimizing the effects of stereotype threat using values-affirmation exercise [36,37].

8. Providing avenues for more hands-on and student-driven learning during class time that enable students develop learning skills such as learning how to learn independently; taking more control for their learning; making presentations; developing their metacognitive skills—knowing what they know, do not know or misunderstand; developing the ability to evaluate themselves, peers, and the teacher [38-41].

Application of Inclusive Teaching in Chemical Engineering

We have been able to demonstrate some aspects of active learning techniques in the teaching of Process Optimization at the University of Port Harcourt. In this course, the students are put in groups of maximum of five students. Each group is expected to carry out an in-class work emanating from problem solving during the lecture, although, guided by the course Lecturer. Upon submission, the work is usually graded, and constructive feedback provided to the students. However, the use of technologies such as Piazza, Google form, and Jot form was introduced into the course during the 2015 students' set. The course outline describing the learning objectives, intended learning outcomes, syllabus, reading assignment, course and assessment schedules and other relevant information were provided on the first day of the lecture. The outline, course materials, and homework were made available on the Piazza platform, and were accessible to all the students. The Piazza platform was also used to promote problem solving as students could post questions and get clarifications from students or course Lecturer. The students were encouraged to submit their homework through the Google and Jot forms, and in their respective groups present a mini project on any case-study involving the application of chemical engineering optimization. As shown in Figure 4, the number of students who made (A+B+C) grades.

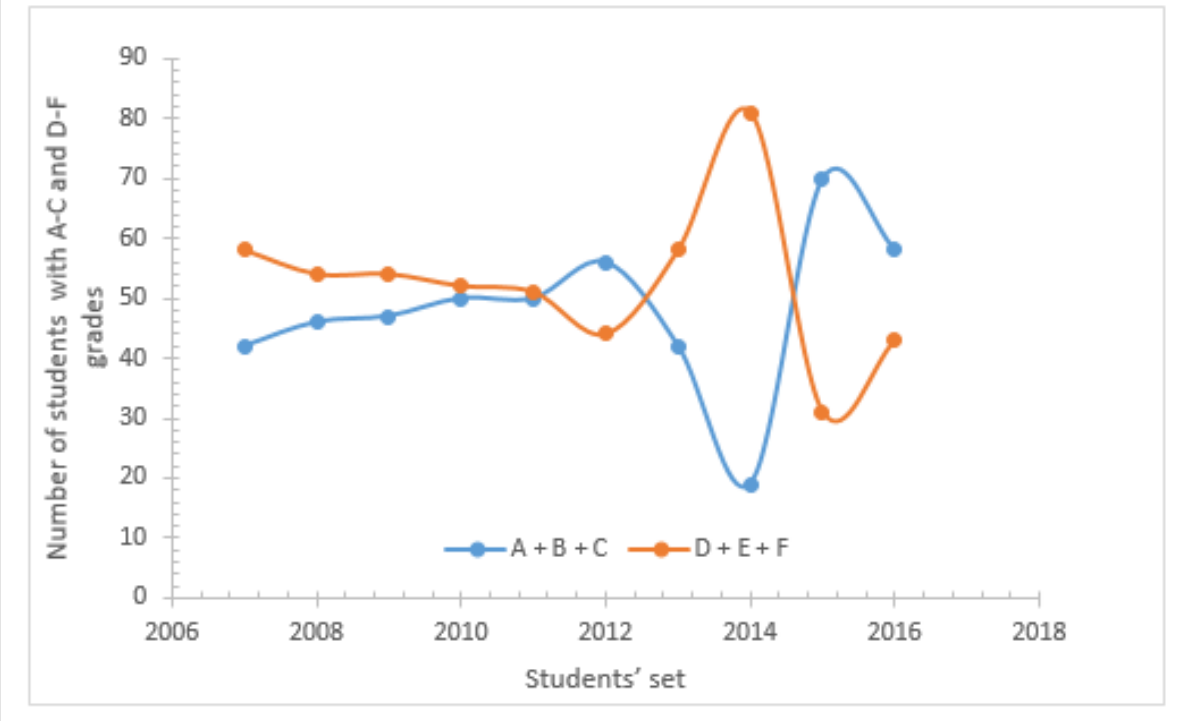

Figure 4: Result of students in Process Optimization over a period of ten years showing A-C and D-F grades, respectively.

Increased from 42 in 2017 to 56 in the 2012 students sets, respectively before declining to 19 in the 2014 students set. Conversely, the number of the students that had (D+E+F) grades decreased from 58 to 14 between 2007 and 2012 sets, until in the 2013 set when it began to increase and reached a peak of 81 in the 2014 set. From Figure 5, it could be observed that there was a decrease in the failure rate in the course between the 2007 and 2011 students sets and the number of the students that failed was higher than those that passed, until in 2012 set when the reverse was the case, after which in 2013 set, the number of students that failed was greater

than those that passed and it was highest in 2014. Since the teaching method used to teach the 2007 to 2014 sets was the same, the decline in performance could be attributed to the academic capability of the students. Upon the improvement of the teaching method in the 2015 set, the performance of the students in the course increased and was highest throughout the ten-year period under consideration. There was a decline in 2016 set, probably due to the strength of the exam questions, and ability to use the technology, especially in submitting their assignments to meet deadlines. Despite the decline in the 2016 set, the performance was greater than the highest obtained in 2012 set when there was no use of technology.

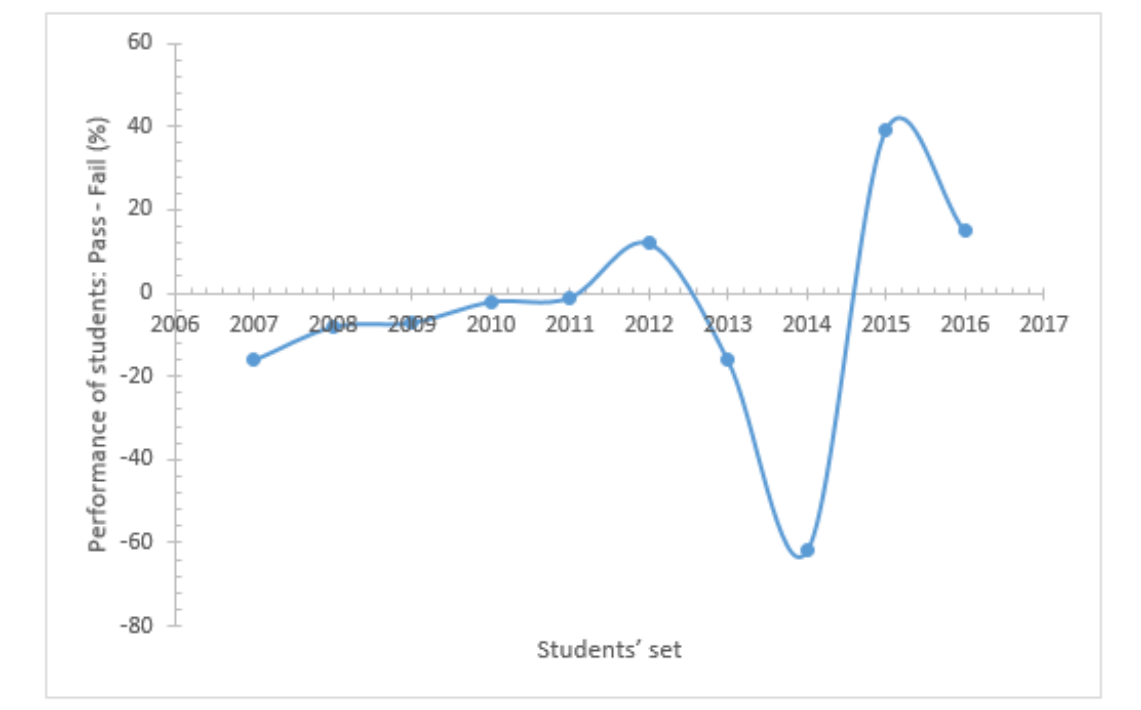

Figure 5: Performance of students in the Process Optimization course between 2007 and 2016 students' sets.

Conclusion

The diversity in the population of chemical engineering students in the tertiary institutions and the generational gap between the lecturers and students may result to low academic performance coupled with the use of traditional teacher centered teaching approach that is prevalent in most institutions. Lecturers at different generations should adapt to the generations of the students and employ inclusive teaching to help to remove the barriers created by the diversity to ensure full participation of students in learning activities, fairness and equity in teaching and assessment, ensure that the students enjoy total autonomy of their own learning and reduces apprehension in the class. This helps to create the right class climate that increases motivation and possibility of working with the instructor's feedback, ensure positive attitude towards the course, and encourages independent learning with the overarching benefits of improved academic performance and personal development.

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