Peeling Back the Layers: Exploring the Deeper Impact of Project-Based Learning on First-Year African Engineering Students

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Introduction

This Complete Research Paper quantitatively examines the experiences of first-year engineering students as they engage in project-based learning (PBL) at Ashesi University, a small, pan-African university in Ghana. This pedagogy presents a significant departure from the rote learning techniques prevalent in many of their high schools. Rote learning emphasizes memorization and repetition, leaving many African graduates with strong theoretical knowledge but insufficient practical skills essential to engineering. Many stakeholders bemoan this challenge of graduates being under-equipped to meet the demands of a rapidly evolving job market. This can, in turn, lead to false perceptions of innovation being unable to unfold on the continent.

Previous studies on a similar student population sought to uncover the impact of this pedagogy and found notable effects on students' self-efficacy, agency, and self-determination [1-3]. The author team, however, wondered whether these constructs might fully capture the impact on these students. Given that those constructs were developed in a Western context and have largely been used there, some gaps may arise when relying solely on them. The author team interviewed a few students who had previously taken this course to determine which aspects of themselves they identified as having been impacted by the course [4]. The insights from this interview were used to inform the development of a survey with four constructs: three existing ones from literature [5], [6] and one author-developed construct.

This survey captures four sets of skills and personal attributes that the interviews identified as areas in which past students reported being impacted. These include: Groupwork Skills (GW), Interpersonal Skills (IS), Problem-Solving Skills (PS), and Potential in Africa/Self (PIA). There is another set of items that measures various aspects of their personal development, but it is not strong enough to be classified under any of the four constructs. It is labeled here as Personal Evolution (PE). Questions on Groupwork Skills and Problem-Solving Skills were obtained from the *"Development and validation of group work skills questionnaire for higher education*" [5] and "*Development of Problem-Solving Confidence Questionnaire: Study of Validation and Reliability*" [6], respectively. Potential in Africa/Self, Interpersonal Skills, and Personal Evolution questions were drawn from emergent insights from the interviews. Groupwork Skills (GW) are essential for engineers as they often collaborate in teams to solve complex problems. These may not have been widely used in these students' pre-university experience. Interpersonal Skills (IS) relate to the ability to communicate effectively and build relationships, both of which are key to teamwork and collaboration. Problem-Solving Skills (PS) are fundamental to engineering, as students learn to analyze problems and devise innovative solutions. Finally, Potential in Africa/Self (PIA) seeks to capture students' perceptions and aspirations to make a positive impact in their context.

About the Course

The Introduction to Engineering course is mandated for all first-year engineering students within Ashesi University’s four engineering majors: Mechanical, Electrical and Electronics, Computer, and Mechatronics Engineering. In the 2025 year group, 107 students enrolled in the course, spread across two cohorts. Students engaged in a series of skills-building modules that equipped them in design thinking, computer-aided design (CAD), fabrication, circuit design, and programming. They concluded the course with a final project that required them to apply these skills as they worked in teams to design and build an engineering solution to a local challenge. Students were assigned to groups of 5-6 members, with a fairly even distribution of engineering majors and genders. This year's class was tasked with designing, building, and automating a small-scale elevator model for a new building on campus. The elevator was to be called “Atumpan Soro”, the Rising Drum, referring to how the African talking drum can lift messages to the sky and bring wisdom down. Using aluminum profiles, V-wheels, and other basic items, students designed a structure, a lifting mechanism, and a control panel that allowed the cab to start and stop at specified floors.

Hands-on, Project-Based Learning (PBL) is the foundational pedagogy for this course. For the past several years, PBL has emerged as a cornerstone of modern engineering education with a focus on experiential learning. PBL fosters a deeper understanding of engineering principles by situating them within complex, real-world problems [7], [8]. In the first year, this approach is critical as it reduces attrition rates by making abstract concepts tangible through real-world applications [9].

Groupwork and Interpersonal Skills

Engineering is inherently collaborative, yet traditional curricula often prioritize individual technical mastery. Students' participation in collaborative learning promotes effective content learning through peer interaction [10]. In the PBL context, engineering students who engage in collaborative projects can show marked improvements in conflict resolution and technical communication [11]. However, these skills do not emerge spontaneously but rather require the type of structured environment provided by PBL to transform group work into effective teamwork [12]. According to Bandura, vicarious experiences are one means of building self-efficacy [13]. Within a PBL team, students can observe peers succeeding at complex tasks. When students learn by observing others face challenges, encounter setbacks, make new attempts, and ultimately achieve success, they can develop self-efficacy [14]. Groupwork also offers the opportunity for social persuasion, another means of building self-efficacy [13]. The mentorship model of PBL allows teammates to provide feedback that focuses on effort and strategy rather than innate brilliance, helping students to dismantle the fixed mindset about their engineering perceptions and replace it with a growth mindset [15].

Within the African context, groupwork adds an extra layer of complexity and opportunity. Chilisa [16] suggests that collaborative learning in African universities can leverage communal values (such as *Ubuntu*) to enhance peer support. PBL groups often bring together students from diverse backgrounds. Navigating this diversity during the first year is a vital skill that prepares students to work in diverse contexts across the continent.

Problem-Solving

Problem-solving is a core competency for engineers. Jonassen [17] distinguishes between two types of problems: the well-structured textbook problems and ill-structured real-world problems. PBL forces students to engage with the latter, requiring them to define constraints and navigate ambiguity. Students in PBL environments tend to develop better skills in monitoring and adapting their problem-solving strategies than students in traditional lecture-based courses [18].

A significant facet of engineering's purpose in Africa is the drive towards social transformation and the solution of pervasive problems. For African students, engineering pursuits could thus be tied to a social justice or national development orientation [19]. Unlike frameworks in other contexts, which may emphasize individual career goals [20], the pursuit of engineering in Africa can ideally include a component of building interest in using engineering to solve local community challenges [21], [22]. Instead of solely fitting into a global corporate mold, engineering students at Ashesi University are encouraged to learn to solve local, context-specific problems, such as water scarcity or rural electrification.

Potential in Africa/Self

The author-developed *Potential in Africa/Self* construct aims to measure student perceptions of potential for innovation and transformation within the African context. Historically, engineering education in Africa has tended to rely on Eurocentric models, which distance students from local challenges [23] despite the importance of a decolonial pedagogy in empowering students in the Global South [24]. When PBL projects are localized—such as designing drones to monitor a hypothetical African small-scale mining community—students move from being consumers of foreign technology to creators of African solutions. As Gruenewald [25] puts it, learning grounded in a specific place fosters a sense of social responsibility towards that place. By applying PBL to real African sites, students move from abstract mathematics to the state of engineering for social justice [26]. This transition may elevate students' perception of Africa's potential from a place that requires importing innovation to one that generates it.

The *Potential in Africa/Self* construct, therefore, refers to a student's perceived agency to contribute to the continent's development and their belief in Africa as a viable landscape for technological innovation. It serves as a bridge between individual career success and collective continental advancement. As Shizha [23] noted, when African students see their curriculum as a tool to solve African problems, they can stop being spectators of foreign progress and become actors in their own developmental narratives. A student's perception of Potential in Africa is ultimately a component of their professional identity. In engineering, identity is constructed through the performance of engineering work [27]. When this performance takes place within an African problem-solving framework, the student may construct an identity as an African Engineer. This identity is linked to the African Union's Agenda 2063, which identifies science, technology, and innovation as the primary drivers of continental transformation [28].

One barrier to realizing this construct is the pervasive dynamic of brain drain. This high-skilled migration is often driven by the perception that local environments lack the infrastructure for professional growth [29]. PBL, however, offers a path to challenge this by repositioning the African landscape as a frontier of innovation rather than a site of scarcity. When students engage in projects that require frugal innovation, for instance, achieving high technological impact with limited resources, they can develop frugal grit [30]. This shift can enable students to see their engineering potential not as a ticket out of the continent, but as the essential capital required to build the very infrastructure they feel is lacking.

This construct shares some similarities with that of Bandura's self-efficacy [13]. For first-year students, the transition to engineering can be daunting. According to the Social Cognitive Career Theory (SCCT), students who experience early success in mastery tasks (such as a PBL project) are more likely to persist in the field [31]. Self-efficacy is therefore a stronger predictor of academic performance than actual ability, as it dictates the level of effort and resilience a student applies when facing obstacles [32]. *Potential in Self,* which is a subset of the *Potential in Africa/Self* construct, is fundamentally an evolution of a student's self-efficacy—their belief in their ability to execute tasks at the desired level of efficiency [13]. In first-year engineering, this self-perception is highly volatile. Lent et al. [31] noted that a student's sense of their own potential is the primary driver of their academic persistence and career aspirations. A significant source of self-efficacy is the mastery experience [13], but traditional engineering curricula can delay mastery experiences until senior-year capstone projects, leaving first-year students with high theoretical knowledge and little to no practical experience. On the flip side, by successfully navigating the design, failure, and eventual iteration of a tangible project from the onset, students receive immediate, authentic feedback on their capabilities. Pajares [32] further argues that these early wins are transformative; they provide the cognitive proof a student needs to believe they can handle the rigors of the profession. This shift defines the *Potential in Self* construct as a transition from viewing engineering as a complex subject to be studied to seeing oneself as an agent capable of engineering.

The *Potential in Africa/Self* promotes psychological empowerment. Empowerment within an educational environment signifies a shift from a condition of learned helplessness concerning systemic problems to a state of learned hopefulness [33]. PBL can restore the student's historical agency. This restoration can enable first-year students to recognize their potential to engineer the future of this continent, transforming their professional identity into a force for continental transformation.

Research Question

This study is guided by the following research question: To what extent are Groupwork Skills, Interpersonal Skills, Problem-Solving Skills, and Potential in Africa/Self dimensions along which first-year African engineering students are impacted by a hands-on, project-based learning course? Quantitatively measuring these dimensions can help confirm what emerged from interviews with students from previous cohorts. In particular, the author-developed construct offers an opportunity to peel back the layers of the impact on this student population. This may begin to provide insight into the underlying contextual aspects of the students' experience here.

Methodology

A retrospective pre-post survey was deployed in April 2025, the last week of the course, to all 107 members of the Introduction to Engineering course via the class mailing list. A retrospective pre-post survey is a method in which the pre-test and post-test are administered simultaneously at the end of an intervention using a single survey, and participants rate themselves through self-reflection [34]. This survey type was chosen because it has been shown to reduce self-assessment bias in this target population [4]. The first question on the survey gauged their level of experience. The rest of the survey used Likert-scale questions to facilitate quantitative analysis. The constructs in question were assessed through 6-7 items each. Participation in the survey was not mandatory; however, students received multiple reminders to complete it.

Existing Level Of Design-Build Experience

Students were first asked about their pre-university experience designing and fabricating anything. This was elicited through a Yes/No prompt. An open-ended response space allowed them to indicate where they had this experience, if any, and what they worked on.

Potential In Africa/Self (PIA) Survey Items

The PIA section of the survey consisted of seven items. They are as follows:

- *I see myself as capable of solving problems I identify around me*

This prompt seeks to assess students' confidence in their ability to identify and tackle challenges in their surroundings.

- *I am capable of designing and building solutions to problems I identify around me.*

This prompt assesses students' ability to see themselves not only as individuals who identify problems but also as active creators of solutions.

- *I see myself as a local innovator.*

This prompt aims to determine whether students see themselves as someone who is an active participant and driver of innovation in their own context.

- *I see myself as capable of creating technologies that will improve lives*

This prompt assesses students' belief in their ability to develop meaningful technologies.

- *I see the possibility of technological advancement in Africa*

This prompt aims to evaluate students' perceptions of Africa's role in the global technology landscape.

- *I see Africa as a place where technology and innovation are produced*

This prompt aims to gauge students' perspectives on the extent to which Africa is a producer or consumer of technology.

- *I believe Africa's technical challenges can be addressed by local engineers.*

This final prompt assesses students' views on the capacity of local human resources to develop solutions that meet the specific needs of their communities.

Quantitative Analysis

Three quantitative methods: Exploratory Factor Analysis (EFA), paired t-tests, and Hedge's g-tests were utilized to analyze the data from the responses. Statistical procedures were performed using SPSS and Microsoft Excel. EFA was used to assess the internal consistency of the survey items. t-tests and Hedge's g-tests were used to assess the statistical significance and effect sizes of the reported changes.

EFA is exploratory; therefore, the number of underlying factors is not known a priori, and one of the key determinants of its successful application is the number of factors to retain [35]. The EFA was conducted on both the pre-survey and post-survey time points within the retrospective survey. As Clarke and Bowles [36] put it, a factor loading of 0.2 is considered small, 0.5 moderate, and 0.7 high. (p. 549). As detailed in the widely cited Comrey and Lee [37], a factor loading value (f) less than 0.44 is considered poor, a value $0.44 < f < 0.54$ is considered fair, a value $0.55 < f < 0.62$ is considered good, a value $0.63 < f < 0.70$ is considered as very good and a value $f > 0.70$ is considered as excellent. The EFA factor loadings helped identify the underlying relationships among variables and confirmed the reliability of the measurement scales used.

EFA was used at both the construct and survey levels to assess the internal consistency of the construct items and the survey as a whole. Evaluating internal consistency at the construct level assumes unidimensionality [38], and given that the EFA identified four distinct latent factors, calculating a global Cronbach's alpha (α) for the entire instrument would be mathematically inappropriate, as α assumes that all items reflect a single underlying trait [39]. Evaluating reliability coefficients for each specific construct provides precision in assessing the measurement model's stability and prevents the inaccurate alpha values often obtained in high-item-count surveys, known as alpha inflation [40]. This approach ensures that the scores used in subsequent hypothesis testing are representative of the specific constructs they are intended to measure, thereby enhancing the study's overall structural validity [41]. According to George and Mallery [42], an alpha value (α) less than 0.5 is considered unacceptable, $0.5 < \alpha < 0.6$ is poor, $0.6 < \alpha < 0.7$ is questionable, $0.7 < \alpha < 0.8$ is acceptable, $0.8 < \alpha < 0.9$ is good, and $\alpha > 0.9$ is considered excellent.

After establishing internal consistency, a paired t-test was conducted to assess differences in students' self-perception scores between the pre- and post-survey assessments. A Hedges' g test was also used to measure the effect size by quantifying the difference between the two means using their standard deviations [43]. A Hedge's g value less than 0.2 is interpreted as a small effect size, $0.2 < g < 0.5$ is interpreted as a medium effect size, $0.5 < g < 0.8$ is interpreted as large, and $g > 1.2$ is interpreted as very large [44], [45]. Figure 1 summarizes the study design.

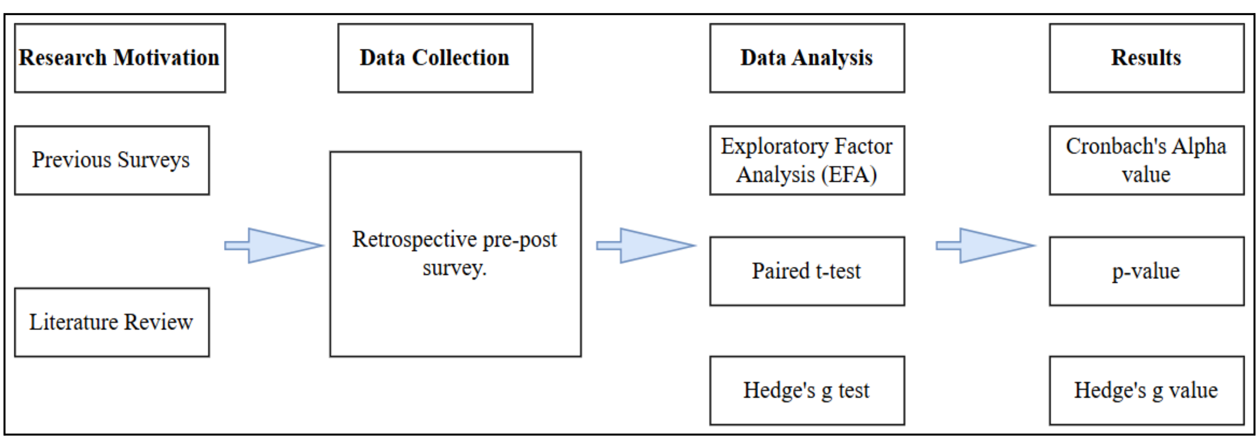

Figure 1: Study Design

Author Positionality

Data analysis was conducted by the first author, a Research Assistant in engineering education research. He is a Ghanaian and an alumnus of the university where this study was conducted. The second author is an American who has lived in Ghana for several years. She was the lead faculty member for the course in view. As this is a quantitative study, the statistical methods employed minimize subjectivity; however, the authors recognize that their respective backgrounds and perspectives should be considered with regard to the overall study design, including the selection of the survey constructs in view.

Results

Out of 107 students total across both cohorts, 85 completed the survey, representing 79% of the entire class. This group consisted of 38 females and 47 males. About 34% of the respondents were majoring in Computer Engineering, 30% in Electrical and Electronics Engineering, 21% in Mechanical Engineering, and the remaining 15% in Mechatronics Engineering.

Existing Level Of Design-Build Experience

Approximately 79% of the respondents cited no prior design-build experience. This is very similar to the data reported by the same population in a previous year group [1]. Hence, it can be understood that hands-on, project-based experiences are generally not common in their prior experience before university. Of those who reported having such experiences, a number mentioned pre-tertiary STEM programs organized by tertiary institutions, notably Ashesi University's *Ashesi Innovation Experience (AIX) Program* [46], as avenues that offered them that opportunity. Hence, the traditional high school experience often lacked these experiences.

Pre-Post Changes

The means of the self-ratings for the studied constructs showed a positive change between the pre and post time points, as captured in Table 1. On a scale from 1 to 10, GW went from an average self-rating of 6.79 to 7.23, which equals an increase of 0.44. Mean scores of IP increased by 0.16, and that of PS by 0.55. Notably, PIA showed the greatest change: 0.86.

Paired t-tests yielded p-values less than 5% across board, indicating high statistical significance for all pre-post changes. The quantitative results for PIA showed a p-value of 4.85E-11, indicating a highly significant effect. A Hedge's *g* analysis of the constructs also revealed small to medium effect sizes across board. Specifically, Groupwork Skills (GW), Interpersonal Skills (IS), Potential in Africa/Self (PIA), and Personal Evolution revealed small effect sizes, and Problem-Solving Skills (PS) revealed a medium effect size.

Table 1: p-values of differences in results between retrospective pre-post survey data

Category	Mean (pre), out of 10	Mean (post), out of 10	p-value	Hedge's g	Effect size
Groupwork Skills (GW)	6.79	7.23	8.49E-05***	0.134	Small
Interpersonal Skills (IS)	7.12	7.28	1.57E-02**	0.169	Small
Problem-Solving Skills (PS)	6.52	7.07	9.73E-08***	0.536	Medium
Potential in Africa/Self (PIA)	6.52	7.38	4.85E-11***	0.275	Small
Personal Evolution	6.44	7.09	1.77E-06***	0.194	Small

**p<= 0.05*
***p<= 0.01*
****p<=0.001*

Within the Potential in Africa/Self (PIA) construct, all seven items demonstrated positive changes between the two time points, on average. This indicates that students developed a more optimistic and empowering view of their potential and that of Africa as a whole after participating in the PBL course. As observed in Figure 2, changes in the extreme ratings on the scale, for instance, 1-2 and 8-10, are more pronounced, with the greatest change occurring at the 10 rating. Higher scores increased, and lower scores decreased by the end of the course. Cumulatively, the frequency of the 10 rating increased by 30% across the two timepoints- the largest difference in self-ratings in the PIA construct. Responses to specific survey items on the PIA construct further reveal the phenomena at play. For example, in the pre-survey, when asked whether they saw themselves as capable of solving problems around them, only 12 students rated themselves at the highest level of 10. This figure surged up by 92% in the post-survey.

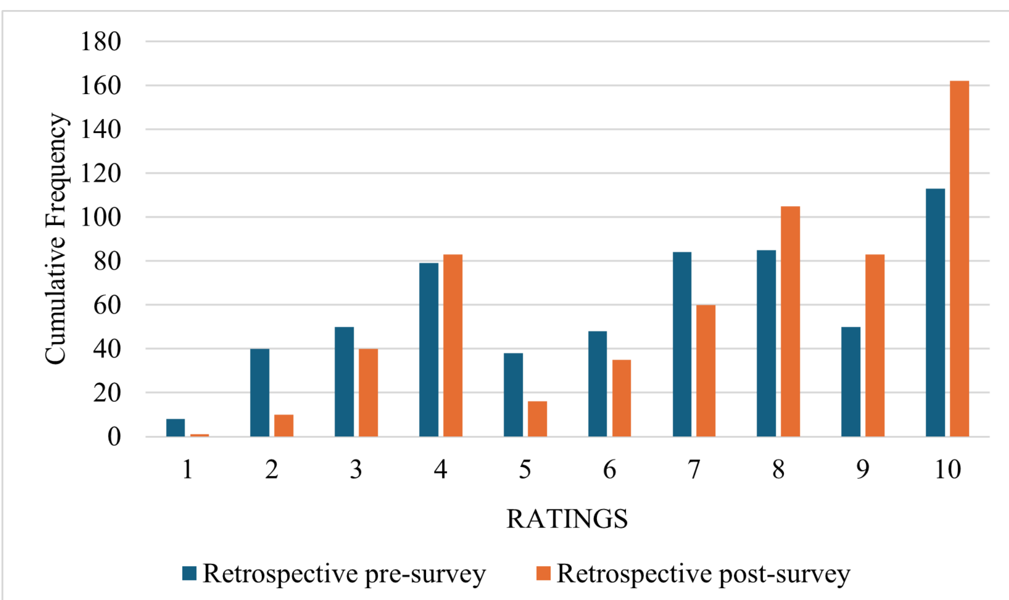

Figure 2: Cumulative changes in self-ratings for the PIA construct

Exploratory Factor Analysis

The EFA of the retrospective pre-survey responses yielded 4 factors, as shown in Table 3. All items in the Group Work and Interpersonal Skills sections loaded together, suggesting that these two constructs could be merged. Items from the Personal Evolution section partially loaded together and partially with items in Problem-Solving. All items in the Potential in Africa/Self section loaded together, indicating that this construct can stand on its own.

Table 3: Factor loadings of retrospective pre-survey questions

	Component			
Item	**1**	**2**	**3**	**4**
GW01			0.657	
GW02			0.656	
GW03			0.55	
GW04			0.7	
GW05			0.587	
GW06			0.737	
GW07			0.66	
IP01			0.726	
IP02			0.606	
IP03			0.673	
IP04			0.695	
IP05			0.622	
IP06			0.525	
PS01	0.656			
PS02	0.773			
PS03	0.688			
PS04	0.671			
PS05	0.697			
PS06			0.374	
PIA01		0.776		
PIA02		0.75		
PIA03		0.768		
PIA04		0.843		
PIA05		0.646		
PIA06		0.752		
PIA07		0.571		
PE01				0.632
PE02				0.619
PE03	0.638			
PE04	0.559			
PE05	0.520			
PE06				0.538
PE07				0.572

At the survey level, Cronbach's alpha values of 0.957 and 0.971 were obtained for the pre- and post-time points, respectively. This indicates strong internal consistency within the dataset as a whole. These results are shown in Table 4.

Table 4: Survey-level Cronbach's alpha scores

Survey	Cronbach's Alpha	Number of questions
Retrospective pre-survey	0.957	35
Retrospective post-survey	0.971	35

At the construct-level, all Cronbach's alpha values exceeded the acceptable threshold ($\alpha > 0.7$). As displayed in Table 5, in the retrospective pre-survey, all showed excellent reliability ($\alpha > 0.9$). The lowest value was measured on PIA at the post-time point. This is not unexpected as the construct was newly generated. The value still denotes an acceptable level of reliability. Hence, the degree of internal consistency within each construct indicates that their respective items are sufficiently unified in their measurement.

Table 5: Construct-level Cronbach's alpha scores

	Cronbach's Alpha	
Category	Retrospective Pre-survey	Retrospective Post-survey
Groupwork Skills (GW)	0.965	0.963
Interpersonal Skills (IP)	0.941	0.932
Problem Solving Skills (PS)	0.929	0.940
Potential in Africa/Self (PIA)	0.965	0.767
Personal Evolution (PE)	0.955	0.960

Discussion

In this study, first-year African engineering students reported significant increases across all measured constructs within a hands-on, Project-Based Learning (PBL) course. Notably, the author-developed Potential in Africa/Self (PIA) construct yielded the lowest p-value among the constructs measured ($p < .001$). This indicates that there is indeed a deeper layer of localized meaning beyond what PBL efforts have traditionally focused on. It suggests that for African engineering students, in addition to skill acquisition, mindset/perception transformation is also at play in a meaningful way. It suggests that when students engage in hands-on learning through PBL, they can begin to dismantle internalized deficit narratives—the pervasive stereotypes that underestimate African technological ingenuity [47]. By moving beyond abstract theory to hands-on, problem-solving, African engineering students can transition from being consumers of foreign technology to active architects of local solutions. This may hold some connection to engineering identity, in a contextualized manner. Other studies indicate that engineering identity is a primary predictor of persistence and retention, particularly for underrepresented or marginalized groups [48], [49]. This could therefore be significant for students developing the resilience needed to navigate the rigorous academic path of engineering, as well as future professional challenges.

Beyond the specific context in view here, this study's findings point to the general value of Place-Based Education (PBE), a pedagogical method that emphasizes the relationship between the learning experience and the physical, social, and cultural environments in which both teachers and students are situated [50]. By shifting the classroom focus toward local contexts and lived experiences, PBE seeks to increase student engagement and foster a sense of civic responsibility. For African engineering education programs, which have historically relied on Eurocentric models that can disconnect students from local challenges [23], [47], PBE offers a pathway to bridge this gap. It integrates the curriculum with community concerns, ensuring that students understand how technical concepts manifest within their unique geographical and socio-economic contexts [51]. This immersion in the immediate environment helps students develop a *sense of place* [25].

The course in view holds synergy between Project-Based Learning (PBL) and Place-Based Education (PBE), with PBL serving as an effective vehicle for implementing PBE's principles. When first-year African engineering students were exposed to homegrown problems—challenges specifically curated from their own communities—through a PBL-intensive course, the self-reported gains were noteworthy. The data indicate that their perceptions of their own potential and of Africa's technological potential improved significantly. Other contexts facing brain-drain challenges and/or a lack of civic engagement among engineering students can utilize such an integrated PBL-PBE approach to ground technical mastery in local relevance.

Limitations and Future Work

This study was conducted within a single class at a single institution in Africa. As a result, the application of the findings might not be wholly generalizable to other educational contexts or cultures across the continent. The institution's unique characteristics, the student body's demographics, and the specific curriculum may all influence the outcomes observed in this research. Other factors could also impact an individual's responses to the Potential in Africa/Self construct. Beyond the classroom, for example, interactions with peers, extracurricular offerings, family dynamics, political systems, and personal achievements or failures could have played a role in shaping how students viewed themselves during this period.

Future research should employ qualitative methodologies to pursue a more in-depth exploration of this layer of impact. Hearing students' personal narratives on this specific layer can provide richer insights into what this quantitative analysis has uncovered. It can allow for the revealing of nuance and variation, which would aid in identifying any of the other factors mentioned above. Interviews and focus groups should be used to delve deeper into the hypothesis that PBL provides a space where identity and technical capability intersect, producing a new generation of engineers more likely to embrace their roles as civic agents, contributing to a necessary evolution of the global narrative regarding African potential [16]. These findings can offer valuable insights for educational practices and policies aimed at enhancing engineering education in Africa. And more broadly, this can encourage a contextually-based approach to similar research efforts globally.

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