A preliminary exploration of the relevance of self-efficacy, self-determination, and agency in describing the first-year African engineering students' experience

Dr. Heather Beem, Ashesi University

Heather R. Beem is a Mechanical Engineering Faculty at Ashesi University in Ghana, where she leads the Ashesi Resourceful Engineering Lab. Her research explores the mechanisms and manifestations of resourceful design, particularly in indigenous innovation, experiential education, and bio-inspired fluid dynamics. Dr. Beem completed her Ph.D. in Mechanical Engineering at MIT/WHOI, and moved thereafter to Ghana, where she founded and leads Practical Education Network (PEN), a STEM education nonprofit building the capacity of African STEM teachers to employ practical pedagogies.

Charity Obaa Afi Ampomah, Ashesi University

Charity Ampomah is a Research Assistant at Ashesi University with the Ashesi Resourceful Engineering Lab. She received her bachelor's degree in electrical and Electronics Engineering from Ashesi University. She is the lead on Educational Experiential Learning research on students at the university level. In addition to research, Charity is also involved in several outreach programs helping young women in their journey in tech.

Jeremiah Paul Konadu Takyi

Jeremiah Takyi completed Ashesi University in 2020 with a bachelor's degree in mechanical engineering. He is currently the Lab Manager for the Ashesi Resourceful Engineering Lab (AREL), where he supervises and supports both educational and engineering-based research projects. As part of being the Lab Manager at AREL, Jeremiah has spearheaded unique projects to develop the fluids lab. He also plays a vital role as the mechanical designer for an emerging up-cycling and down-cycling textile firm. Jeremiah believes in diligence.

Gordon Adomdza

Dr. Gordon Kwesi Adomdza is Associate Professor of Entrepreneurship and Innovation, Ashesi University. He teaches courses that use Design Thinking to develop innovative concepts for new ideas and business models. He is the faculty lead of the Ashesi Entrepreneurship Centre, which among other programs, runs the Ashesi Venture Incubator. Previously, he taught design thinking and entrepreneurship at the D'Amore-McKim School of Business, at Northeastern University, Boston, MA for 7 years. Dr. Adomdza graduated from University of Waterloo, Ontario, Canada with a Ph.D in Management of Technology MASc in Management Science and MA in Applied Economics. Dr. Adomdza's research interests are in the area of allocating resources for discovering and validating opportunities for entrepreneurs, as well as the idea-forming process for the development of new products.

A preliminary exploration of the relevance of self-efficacy, self-determination, and agency in describing the first-year African engineering students' experience

Abstract

Students on the African continent may embark on some of their first hands-on, project-based learning experiences as they begin engineering programs in university. Such learning experiences can help effect significant transformation in their self-perceptions. Previous work indicates that students at Ashesi University in Ghana increase significantly in self-efficacy as they engage in project-based coursework in their first semester. Given some critiques of the self-efficacy construct itself, it behooves a consideration of a broader scope of constructs that may aptly describe African students' unique position in this experience. This paper serves as a preliminary exploration of the self-efficacy, self-determination, and agency constructs as potential options in this pursuit.

ANOVA and t-tests conducted on surveys administered to students at the beginning and end of their first semester indicate that self-determination and agency are significantly higher than self-efficacy at the beginning. By the end of their first semester, both self-efficacy and agency significantly increase. The same trend held for both engineering and non-engineering students, and slight deviations appeared with further levels of disaggregation. Semi-structured interviews conducted with second- and third-year engineering students suggest consistency with this trend and reveal a few more constructs and attributes that could be considered in the exploration.

Exploratory factor analysis indicated that when survey questions were better aligned with items from existing scales, the factor loadings tended to fall cleanly within each of the three existing constructs.

A small number of survey questions per construct were provided in order to avoid burdening the students, however this proved to be a limitation in the analysis. Future work should extend the exploration broader to new constructs and deeper within them. Identification of a relevant construct or set of constructs that describe the African engineering student's experience can help enable better educational outcomes on the continent.

KEYWORDS

self-efficacy, self-determination, agency, Africa, first-year

Introduction

Due to the dominance of rote pedagogies in many pre-tertiary classrooms, African students entering a university engineering program may tend to have had limited design-build

experiences. This can affect their academic prospects, but perhaps more importantly it can build a negative perception of their capabilities in creating innovations and developing technical solutions.

A first-semester engineering course, Introduction to Engineering, has been seen to have an impact in countering this perception in students at Ashesi University in Ghana [1] [2]. The course's modules which include machine shop skills-building sessions and project-based learning offer causality for statistically significant increases in students' self-efficacy. These significant increases were maintained even with a change in physical environment, as a similar course, Principles of Design was offered online during the COVID-19 pandemic and students conducted hands-on activities from their homes across the continent [3]. It is clear that these students are experiencing a transformation in thought and self-perception as they begin their university engineering journey and engage in this largely new type of coursework.

Although self-efficacy, "people's beliefs about their capabilities to produce designated levels of performance that exercise influence over events that affect their lives" [11], is the construct which the authors have relied on up to this point to explore this transformation, there is cause to warrant a broader exploration of relevant constructs. First, there is concern that self-efficacy can be considered as a deficit-based construct. Second, its creation in the American context may not translate directly to the African context. [4] compared results on the General Self-Efficacy Scale across 25 countries and found some variation in the internal consistency across countries, based on the range of Cronbach's alpha values, a reliability measure, seen. Most of these countries were located in the Global North, and no single African country was included in the study. It is therefore possible that the self-efficacy construct may not be as relevant to our students as those in other contexts. Third, some limitations of the self-efficacy construct have been identified. One such is a critique that the construct serves more as a reflection of motivation rather than a determinant and therefore researchers should endeavor to understand the various sources of self-efficacy in greater depth in order to interpret its meaning [5]. These insights motivate a deeper investigation into the relevance of self-efficacy in this context.

Our students' transformation as they undergo design-build experiences is likely multi-faceted. A seeming increase in confidence, ergo self-efficacy, stood out in the lead author's initial observations. Through reflection and discussion with colleagues at the university, two other possible experiences emerge for investigation. Students may be drawing from/building on resilience formed from their past experiences, such as hurdles they overcame to become scholarship recipients at our university, translating/manifesting that to tackle the new challenge of completing design-build projects. Students could also be experiencing a greater sense of control and power over their actions, and thereby their future prospects, as they engage in design-build work.

In order to ascertain which existing constructs could best describe these additional two experiences, a brief survey of student development theories and constructs was conducted. The

key theories behind several constructs, including self-determination, agency, self-authorship, ecological systems theory, community cultural wealth, hope theory, validation theory, and capacity to aspire among others, were investigated. Self-determination and agency emerged as the best fit for each of the two experiences, respectively. While many researchers have looked at self-determination as a construct to aid in the retention of women in engineering [6], none to the authors' knowledge have used it in describing the experiences of first-year African engineering students. Self-determination theory suggests that humans strive toward goals that are either nurtured or hindered based on social or cultural factors that affect their basic needs for competence, autonomy, and relatedness [7]. It proposes that satisfying these basic needs for competence, autonomy, and relatedness increases intrinsic motivation [8]. In simple terms, *autonomy* is the need to feel in control over your actions and decisions. *Competence* is the need to have the ability to effectively engage in activities. *Relatedness* is the need to have a sense of belonging and acceptance to an environment or community. In pursuing academic goals, intrinsically motivated students freely engage in activities that they deem interesting and inherently satisfying. The self-determination continuum describes how people's motivation varies from amotivation to intrinsic motivation [7]. Amotivated students often lack the initiative to perform and do not perceive the importance of tasks whilst intrinsically motivated ones see the need to execute and act out of interest and self-satisfaction. Although extrinsic motivation is often associated with low academic performance, not all extrinsically motivated acts lead to low performance [9]. Ryan and Deci suggest that, depending on the amount of autonomy given, an extrinsic motivation could lead to autonomous or controlled motivation [8]. An autonomously motivated student placing value on class activities oftentimes is influenced by a desire to achieve good grades. A good grade, although extrinsic in nature may be a motivation factor to impact students' performance.

Agency theory is based on an individual's ability to make and act on decisions that have the potential to affect their lives [9]. Bandura defines agency as "the power to originate action" [10]. It is possible that when students are engaged in design-build and project-based experiences, they can control their learnings and decision-making process. The collective study of agentic factors is essential in understanding the role agency plays in student learning [11]. Through design-building and project-based learning, it is possible that students can utilize the key agentic factors, which include intentionality, forethought, self-regulation and self-reflectiveness [11].

Other constructs may very well still warrant further consideration, as the exploration deepens and more key experiences are articulated. This paper offers a preliminary exploration of the relevance of a few constructs in describing the transformations that African first-year university students undergo as they engage in hands-on, design-build experiences. Self-efficacy, self-determination, agency will be in focus, with an open eye for other constructs that emerge. This preliminary step can serve to guide researchers in knowing which constructs warrant more in-depth investigation for understanding their relevance to the African first-year student experience.

Methods

In the latter part of 2022, a course called Principles of Design was offered to all incoming students at Ashesi University, which is located in Ghana but draws students from multiple African countries. Nearly 150 students participated in this course, which sought to build foundational design thinking and skills. Students from engineering, computer science, and business administration departments were all required to take the course. The course was co-taught by faculty in engineering and business administration. Students participated in lectures on key design concepts, received tutorials in Computer-Aided Design (CAD) software, and completed 5 hands-on mini-projects, 4 of which were in the form of design-build challenges (see Figure 1 for examples), and 1 of which was in the form of a product teardown. The students participated in the course in an online, asynchronous form. Hence they accessed pre-recorded lectures, tutorial videos, and assignment instructions through the course Canvas page. They were, however, living on campus so they convened in-person for the activities assigned in groups. The university was testing this unique format as it works to make a suite of its "First Year Experience" courses available online and asynchronously for a broad user base across the African continent. A combination of online surveys with these students and interviews with previous years' students were used in this study.

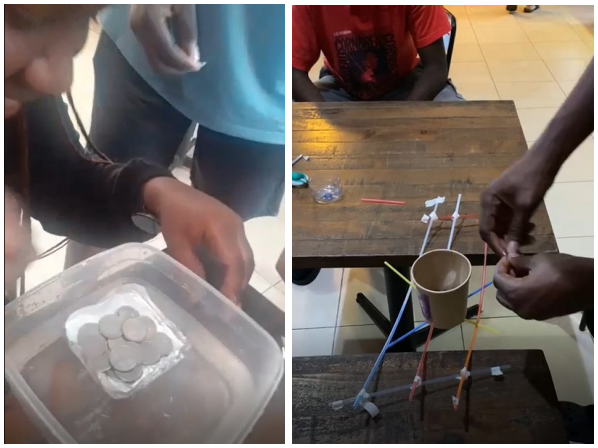

FIGURE 1. Example design-build challenges conducted by the students in the Principles of Design course in 2022. Student teams built solutions to hold as much weight as possible via (Left) an aluminum foil raft and (Right) a plastic straw bridge.

Three surveys were administered online to two incoming batches of first-year students at Ashesi University - two for Batch 1 who joined in September 2022 and one for Batch 2 who joined in January 2023. They were administered at the following timepoints: beginning of Batch 1's first semester (September 2022), end of Batch 1's first semester (December 2022), and start of Batch 2's first semester (January 2023). They will be referred to as pre-survey (2022), post-survey (2022), and pre-survey (2023) in this paper, respectively. Note that the data from Batch 1 includes both Engineering and Non-Engineering students, as all students were required to take the Principles of Design course, whereas data from Batch 2 only includes Engineering students,

as their survey was administered as part of the Introduction to Engineering course. Based on an intention to not overburden the students, each construct was captured using a set of three to six questions, hence a total of nine to thirteen Likert scale questions were asked on each survey. Disaggregations were used to distinguish any differences in results experienced, based on major.

The pre-survey (2022) was administered at the beginning of Batch 1's start of their program. It captured the students' sense of self-efficacy, self-determination, and agency on a Likert scale response from 1 to 5, student's past design-build experiences in a yes/no format, and their demographics. The questions used to assess each construct were created by the authors, based on previous surveys they had run with earlier year groups. The prompts on self-efficacy measures were: "I am confident right now to design something physical", "I am confident right now to build something physical" and "I am confident right now to build something intangible". The prompts on self-determination measures were: "I am willing and determined right now to design a physical item", "I am willing and determined right now to build a physical item", and "I am willing and determined right now to build something intangible (a business, software, system, procedure, etc.)". The prompts on agency measures were: "I am very likely to build something physical with limited resources and capital", "I am very likely to go through with a design with limited resources and capital", and "I am very likely to build an intangible system with limited resources and capital (a business, software, system, procedure, etc.)". The post-survey (2022) was administered at the end of Batch 1's first semester, and it included the same Likert scale questions as the pre-survey.

The pre-survey (2023) was administered at the beginning of Batch 2's start of their program. In an attempt to better align the survey questions with existing scales, the same three constructs were now captured using a revised set of questions. The available response range was from 1 to 10, enabling finer variations in the responses. The questions were adapted from the Basic Psychological Need Satisfaction at Work Scale (Deci, 2021) and Agency for Learning Questionnaire (Code, 2020), modifying them for the engineering context. One question was asked for each of the elements under self-determination, that is a question on autonomy, competence, and relatedness. Similarly, one question was asked for each of the elements under agency for learning, that is self-reflectiveness, self-regulation, forethought-extrinsic, forethought-intrinsic, intentionality- planfulness, and intentionality- decision competence.

Initial Self-Efficacy, Self-Determination, and Agency Levels

Analysis of the initial levels of each of the three constructs was carried out. A single-factor ANOVA analysis was done on the pre-survey (2022) to compare the constructs and assess mean differences. A post hoc analysis was done further using a Tukey HSD test to check for statistically significant differences between the frameworks. These comparisons were performed to determine which constructs students were experiencing at the start of the course. The same analyses were done on the pre-survey (2023). These two results were then compared to ascertain the extent to which a modification in specific questions used had an effect on the results.

Change in Self-Efficacy, Self-Determination, and Agency Levels

Analysis of any change in levels of each of the three constructs was carried out by comparing data captured in the pre-survey (2022) and post-survey (2022). First they were examined in aggregate, and then they were disaggregated across Engineering and Non-Engineering students. A further disaggregation was done for these categories in terms of Women and Men. Unpaired t-tests were conducted between pre and post values of each of the three constructs. Hedge's g tests were used to determine the effect size of any statistically significant difference. The effect size (g) was said to be small if $|g| >= 0.2$, medium if $|g| >= 0.5$, and large if $|g| >= 0.8$.

Factor Analysis

An exploratory factor analysis (EFA) was conducted to understand the factor loading within each of the constructs captured in the post-survey (2022) and pre-survey (2023). Note that for the sake of this analysis, data from participants in Batch 1 were used in both surveys. Because they had written these surveys less than a month apart, and the time between which they were on the holiday break not engaged in any schoolwork, it can be assumed that their responses should have been similar to each other. The Kaiser-Meyer-Olkin measure of sampling adequacy and Bartlett's test of Sphericity were used to assess the factorability of these data. Varimax orthogonal factor rotation method was used in minimizing the variables that had high loadings (0.50 and above) in each factor. The internal consistency and reliability were checked by performing a Cronbach's Alpha test with a threshold of 0.6.

Exploration of Other Constructs

In order to identify other constructs which warrant exploration, students' own narratives were centered, in an attempt to allow constructs to naturally emerge. In order to also allow for some time to have passed and therefore some space for reflection on the experience, second- and third-year engineering students were in focus. Semi-structured interviews were designed, and students were invited to participate in and reflect on their first-year experiences in design-build courses. These students had completed both Principles of Design and Introduction to Engineering courses, which took place for them between 2020-2022. An email asking for volunteers was sent out to both year groups. Nine students volunteered, including 5 women and 4 men. The interviews were designed to last between 30 to 50 minutes. Despite the low sample size, these preliminary interviews can lay the groundwork for more extensive interviews in future work.

The second author carried out the interviews with one student at a time, recording each one. Interviewees were informed of the purpose of the interviews and how the information would be used, assured of their anonymity, and given the option to opt-out. Each interview began with the prompt, "Tell me about your experience in Introduction to Engineering in relation to the final project you did". This narrowed students' retrospection down to the key project-based learning experience. Other questions and prompts included "What did you not like or like about your course?", "How did you feel after completing the course?", "Describe your decision making

process as you went through the course." and "What was your motivation for perseverance in the midst of challenging situations?". The interview allowed for a free flow of conversation about their project experiences, and the interviewer brought forward a few other questions, as appropriate, to guide the conversation.

After the interviews were completed, the experiences that students recollected were categorized according to specific timepoints, that is Beginning, During and After the course. This enabled a better understanding of how their journey developed over time. The Beginning category includes experiences that students described at or near the start of the course including, for example, how they felt about the project at the beginning, their observations from the class and their general outlook of their project before starting. The During category includes experiences that students described while their final project was ongoing. These include, for example, what students said about their project execution, team dynamics and general project execution challenges. The After category includes experiences such as the aftermath of the project, how the project had an influence on their interests, their perception about themselves in relation to their competencies, and a general reflection on the project-based learning approach.

Results

Initial Self-Efficacy, Self-Determination, and Agency Levels

Analysis conducted on Batch 1's initial levels, from pre-survey (2022), is shown in Table 1. The single-factor ANOVA test shows a significant difference ($p < 5E-02$) on students' perception of their self-efficacy, self-determination and agency for the three frameworks [$F(1,2) = 9.83$, $p < 5E-02$]. A Post hoc test using Tukey HSD test shows that the mean score for self-determination ($M=3.69$, $SD = 0.66$) was significantly different from self-efficacy ($M=3.30$, $SD=0.86$). Again the mean score of self-determination ($M= 3.69$, $SD = 0.66$) was significantly different from agency ($M=3.34$, $SD=0.83$). However, agency did not significantly differ from self-efficacy. This indicates that students' self-determination at the start of their time at university is significantly higher than their self-efficacy and agency.

				ANOVA	
	Mean	S.D.	N	F	Sig
Self-Efficacy.	3.30	0.86	134	9.832	6.78E-05***
Self-Determination	3.69	0.66	134		
Agency	3.34	0.83	134		

***$p \leq 0.001$

TABLE 1. Mean, standard deviation and single-factor ANOVA test on pre-survey (2022). Available responses were on a Likert scale of 1 to 5.

The effect of prior design-build experience on these pre-survey (2022) results is shown in Table 2. An unpaired t-test compared students who either cited "yes" or "no" to having had past

experience in “building a physical item”. A statistically significant difference in means was measured for self-efficacy and agency. Self-determination, however, was statistically similar for both groups.

		Mean	N	SD	2-tailed Sig	|g|
Self-Efficacy	No	3.10	78	0.91		
	Yes	3.58	56	0.71	7.78E-04***	0.6
Self-Determination	No	3.64	78	0.59		
	Yes	3.76	56	0.71		
Agency	No	3.19	78	0.86		
	Yes	3.58	56	0.71	4.64E-03**	0.5

$**p \leq 0.01$
$***p \leq 0.001$

TABLE 2: t-test analysis on students who said “yes” or “no” to having had prior design-build experience

Together, these two results indicate that overall, as students enter university, they experience self-determination more significantly than the other two constructs. And if students have had prior design-build experience, they enter university with higher self-efficacy and agency than their peers.

Analysis conducted on Batch 2’s initial levels, from pre-survey (2023), is shown in Table 3. The single-factor ANOVA test shows a significant difference in students' perception of their self-efficacy, self-determination and agency for the three frameworks [$F(1,2) = 54.40$, $p < 5E\text{-}02$]. A post hoc test using Tukey HSD test shows that the mean score for self-determination ($M=7.96$, $SD = 1.52$) was significantly different from self-efficacy ($M=4.49$, $SD=2.20$). Again the mean score of agency ($M= 7.84$, $SD = 1.31$) was significantly different from self-efficacy ($M=4.49$, $SD=2.20$). Compared with the initial levels measured in the pre-survey (2022), this dataset similarly shows self-determination as significantly higher than self-efficacy at the beginning of the students’ university journey. However this dataset deviates from the earlier one in that agency is also significantly higher than self-efficacy here. When the questions were drawn more directly from existing scales, the result was similar but not the same.

			Mean	N	S.D	ANOVA F	Sig
Pre-Survey	Self-Efficacy.	Pre	4.49	43	2.20	56.40	3.2081E-18***
	Agency	Pre	7.84	43	1.31		
	Self-Determination	Pre	7.96	43	1.52		

***$p \leq 0.001$

TABLE 3. Mean, standard deviation and single-factor ANOVA test on pre-survey (2023) for scales adapted from Basic Psychological Need Satisfaction at work Scale and Agency for Learning Questionnaire. Available responses were on a Likert scale of 1 to 10.

Change in Self-Efficacy, Self-Determination, and Agency Levels

Table 4 displays results from the unpaired t-tests conducted on the change between pre-survey (2022) and post-survey (2022). It is seen that students' self-efficacy and agency levels increased significantly over time ($p < 5E-02$) and with medium to large effect sizes ($g >= 0.5$), while self-determination did not change with statistical significance ($p > 5E-02$). The same trend was seen for both the students in aggregate as well as when they were disaggregated by major.

			Mean	N	SD	2-tailed Sig	|g|
All Students	Self-Efficacy	Pre	3.30	133	0.86		
		Post	3.79	89	0.54	6.35E-07***	0.7
	Self-Determination	Pre	3.69	133	0.66		
		Post	3.78	89	0.51	2.39E-01	
	Agency	Pre	3.36	133	0.82		
		Post	3.81	89	0.52	8.89E-05***	0.6
Engineering	Self-Efficacy	Pre	3.26	39	0.79		
		Post	3.77	29	0.40	1.045E-03**	0.8
	Self-Determination	Pre	3.70	39	0.88		
		Post	3.69	29	0.62	9.14E-01	
	Agency	Pre	3.50	39	0.63		
		Post	3.79	29	0.39	2.28E-02*	0.5
Non-Engineering	Self-Efficacy	Pre	3.30	88	0.87		
		Post	3.78	55	0.61	1.68E-04***	0.6
	Self-Determination	Pre	3.72	88	0.60		
		Post	3.81	55	0.54	1.99E-01	
	Agency	Pre	3.42	88	0.87		
		Post	3.79	55	0.58	3.28E-03**	0.7

*$p \leq 0.05$
**$p \leq 0.01$
***$p \leq 0.001$

TABLE 4. t-test analysis on pre-post change for aggregated (All Students) and disaggregated (Engineering and Non-Engineering) data from pre and post surveys (2022)

When disaggregated further (Table 5), a few differences between the groups emerge. Although self-efficacy increased significantly for both men and women engineering students, agency only increased significantly for the former ($p < 5E-02$). The latter, women engineering students, did not increase significantly ($p > 5E-02$). It is interesting to note, however, that women engineering students recorded higher average values on agency at the beginning and end of the course, compared to their male counterparts. Non-engineering men bucked the trend, as they did not display any significant increases in means for any of the three constructs.

Together, these pre-post changes indicate that, in aggregate, self-efficacy and agency increase significantly over the students' experience with design-build coursework. Self-determination remains statistically similar to the relatively high value cited at the beginning of the course.

			Mean	N	SD	2-tailed Sig	|g|
Engineering (Women)	Self-Efficacy	Pre	3.31	13	0.73		
		Post	3.86	11	0.31	2.64E-02*	1.0
	Self-Determination	Pre	3.82	13	0.75		
		Post	3.73	11	0.55	7.31E-01	
	Agency	Pre	3.74	13	0.64		
		Post	3.90	11	0.30	4.18E-01	
Engineering (Men)	Self-Efficacy	Pre	3.24	26	0.83		
		Post	3.72	18	0.45	1.79E-02*	0.7
	Self-Determination	Pre	3.65	26	0.96		
		Post	3.67	18	0.67	9.58E-01	
	Agency	Pre	3.39	26	0.59		
		Post	3.72	18	0.40	3.47E-02*	0.6
Non-Engineering(Women)	Self-Efficacy	Pre	3.15	41	0.94		
		Post	3.88	31	0.59	1.36E-04***	0.9
	Self-Determination	Pre	3.77	41	0.66		
		Post	3.88	31	0.55	4.50E-01	
	Agency	Pre	3.39	41	0.94		
		Post	3.91	31	0.52	3.72E-03**	0.7
Non-Engineering (Men)	Self-Efficacy	Pre	3.43	47	0.79		
		Post	3.64	24	0.62	2.18E-01	
	Self-Determination	Pre	3.68	47	0.54		
		Post	3.72	24	0.52	7.54E-01	
	Agency	Pre	3.45	47	0.81		
		Post	3.63	24	0.63	3.33E-01	

*$p \leq 0.05$
**$p \leq 0.01$
***$p \leq 0.001$

TABLE 5. t-test analysis on disaggregated Engineering (Men and Women) and Non-Engineering (Men and Women) data from pre and post surveys (2022)

Factor Analysis

Results from the varimax rotation on the 9 items of the post-survey (2022) are shown in Table 6. A Kaiser-Meyer-Olkin measure of sampling adequacy was 0.84, which is above the recommended value of .60, and the Bartlett's Test of sphericity was significant ($x^2(36) = 582.254$, $p < 5E\text{-}02$). After rotation, the first factor accounted for 40.4% of the variance and the second factor accounted for 33.3%. Cronbach's alpha for the first and second loadings was α=0.90, 0.88, respectively, which are both greater than the recommended threshold of 0.6. The reliability of these factor loadings indicates that there is a close relationship and internal consistency within the variables of each factor loading. Each of the two factors loads items from each of the three constructs. However, given the relatively small number of items in question, there is not enough evidence to necessitate the creation of a new construct from these results.

	Factor Loadings		
Item	Factor 1	Factor 2	Communities
I am confident right now to design something physical	.83		.75
I am confident right now to build something physical	.83		.75
I am confident right now to build something intangible. (a business, software, system, procedure, etc.)		.84	.74
I am willing and determined right now to build a physical item	.77		.66
I am willing or determined right now to design something physical	.85		.78
I am willing and determined right now to build something intangible. (a business, software, system, procedure, etc.).		.84	.75
I am very likely to build something physical with limited resources and capital		.74	.67
I am very likely to build an intangible system with limited resources and capital. (a business, software, system, procedure, etc	.81		.73
I am very likely to go through with a design with limited resources and capital		.86	.82

NB: loadings <.50 were omitted.
The first three questions capture self-efficacy, the next three self-determination, and the last three capture Agency.

TABLE 6: Factor loadings on a varimax rotation for a two-factor solution for students' self-efficacy, self-determination, and agency on the post survey (2022)

Results from the varimax rotation on the 13 items of the pre-survey (2023) are shown in Table 7. A Kaiser-Meyer-Olkin measure of sampling adequacy was 0.82, which is above the

recommended value of .60, and the Bartlett's Test of sphericity was significant ($x^2(78) = 301.383$, $p < 5E\text{-}02$). After rotation, the first factor accounted for 25% of the variance and the second factor accounted for 23% and the third 18% of the variance. The communalities for each variable were above .30 indicating that each item shared some common variance with other items. Cronbach's alpha for the first, second, and third loadings was α=0.86, 0.83, 0.76, respectively, which is greater than the recommended threshold of 0.6. The reliability of these factor loadings indicates that there is a close relationship and internal consistency within the variables of each factor loading.

Compared to the previous factor analysis (Table 6), this result shows much cleaner loading of items within each of the constructs. Two of the factors draw fully from the items in one construct and the third draws only one item from a second construct. Since the students whose data was used for both analyses are the same, and with survey timepoints less than one month apart, it can be interpreted that a better alignment of items with existing scales provides a cleaner factor loading.

	Factor Loadings			
	Factor 1	Factor 2	Factor 3	Communalities
I am motivated to take this course because I like to learn more about engineering.		.86		.84
I am motivated to take this course because I like to work on something of my choice		.80		.67
I am motivated to take this course because I can easily get along with people, I am placed in a team with		.60		.60
I consider how best to carry out a decision	.78			.66
I feel confident about my ability to make decisions	.85			.86
I am studying engineering because my studies allow me to continue to learn about many things that interest me				.34
I can easily control my emotions even when things are not going so well	.58			.52
I can always motivate myself to do schoolwork	.69			.68
Through engineering, I feel that I can now contribute to solving world problems		.75		.63
how well do you think this course (i.e looking at course description and course outline) can help affirm your decision to study engineering	.73			.55
how confident are you right now to design a circuit			.87	.77
how confident are you right now to write programming code			.75	.62
how confident are you right now to build something using the tools in the Ashesi workshop			.87	.78

NB: *loadings <.50 were omitted.*
The first three questions capture self-determination, the next six capture agency, and the last three capture self-efficacy

TABLE 7: Factor loadings on a varimax rotation for a two-factor solution for students' self-efficacy, self-determination, and agency from pre-survey (2023), Batch 1 students only

Exploration of Other Constructs

In the interviews, as students described their experiences starting out in their first semester, the following appeared as highlights within the Beginning category. Students who entered the university with little to no prior design-build experience spoke about how their lack of exposure in these areas affected their belief in their ability to perform the assigned tasks. They even compared themselves to their counterparts, reporting that those with prior experience appeared more confident and invested in the class. They themselves, however, expressed sentiments like these: “I was unconfident and felt I didn't know anything at the start of the project”, and “Some people appeared more confident as they responded to and asked questions about concepts we had not yet discussed”. Finally, some also highlighted an early eagerness and determination to learn something new, and they attributed this to their interest in studying engineering. These could be interpreted as indications that self-efficacy was low at the beginning, especially for those with minimal relevant experience, and also the presence of self-determination propelling them.

As students recalled their experiences in the midst of the course and conducting their final project, the following appeared as highlights within the During category. Because the course and final project involved aspects of all the three engineering disciplines offered at the university, some students expressed developing a better understanding of what their majors entailed and therefore a clarification of where their interests lie. “Working on the project made me aware of what I liked in relation to engineering,” one student said. “I was able to identify the branch of engineering I felt confident working on,” said another. Students described their experience as involving and demanding. The project required students to lead and take control of the implementation of their project’s solution. It was the first time some had worked on a project that required them to be autonomous. One student described her experience as one of self-learning, indicating that she had to take initiative and go the extra mile in the project: “This project made me realize that I wasn’t going to be spoon-fed like I was back in Senior High School,” she said. Students taking charge of their own learning and decision making for their projects can serve as an indication of their agency. When asked about their motivation for perseverance, some expressed concern about their grades, while others stated a greater concern with the desire to feel fulfilled or satisfied after completing a successful project. These mentions of autonomy and competence could be interpreted as indications of two key elements present in self-determination. Engineering identity and belongingness could also be emerging from the mentions of honing in on their interest areas.

Finally, as students described their experiences after finishing the project and course, the following emerged as highlights within the After category. The majority of interviewees reported an increase in their confidence in hands-on work and a sense that they could now engage in more project-based efforts. One student shared how the experience motivated her to pursue another project: “I wanted to build a self-segregating bin from the little confidence I gained after the project, and I went on to talk to some lecturers about this”. Another student mentioned wanting to use the course knowledge to help design solutions for people with disabilities. Others pinpointed an appetite for tackling additional problems needing to be solved. These mentions of confidence boosts and keenness to search out more projects could be interpreted as indications of increases in self-efficacy and agency.

Conclusion/Discussion

A preliminary step has been conducted to explore a few constructs which may be relevant in describing the first-year African students’ experience as they engage in design-build coursework. Based on comparison of self-reported Likert-scale data, these preliminary results suggest that self-determination may be relevant in describing the initial attitude and mindset adopted by first-year students starting their coursework at Ashesi University, and perhaps in African universities broadly. Students who join university already having had design-build experiences likely draw from that to inform a relatively higher self-efficacy and agency levels compared to their counterparts. Regardless of their level of prior design-build experience, all students tended to express relatively high self-determination levels.

After undergoing the project-based course, in aggregate, students’ self-efficacy and agency increased with statistical significance. It is possible, therefore, that over time the dominant construct describing the students’ experience may shift. It likely behooves researchers to view the student experience as a dynamic transformation. This type of course can have an impact on non-engineering students as well, as their self-efficacy and agency were also seen to increase significantly. These effects are, however, most pronounced on the women students within that category. In future work, it may also be worth exploring why women engineering students reported higher agency scores both at the Beginning and End of the course, compared to their male counterparts.

Results from the exploratory factor analyses conducted suggest that if survey questions are well aligned with existing scales, the existing constructs may indeed capture our students’ experience. A larger number of questions per construct should be used next so as to reliably determine whether existing constructs are indeed sufficient or a new construct warrants creation.

Interviews conducted with second- and third-year engineering students add evidence to the possibility that the dominant experience, and therefore construct, is dynamic, changing from the Beginning to After the design-build coursework. From the sample of students interviewed, a keen eagerness to learn appeared to be propelling them as they started the course. This appears to be consistent with the high level of self-determination measured in the pre-surveys. During the course, their interest in and understanding of engineering grew, while the desire to succeed drove them to persevere through challenges. Afterwards, they expressed a greater sense of confidence and interest in tackling more projects. This also appears to be consistent with the increases in self-efficacy and agency measured in the pre-post survey comparison. Confidence emerged strongly throughout the interviews - starting from a low level at the beginning to a strong level after the course. Hence, despite potential shortcomings of the self-efficacy construct, it warrants further consideration as a relevant construct. Future work could consider revisiting the sources of self-efficacy and/or the specific measures being used to capture it, tailoring it to be more relevant to our students here. Other constructs and unique elements that could be interpreted as having emerged from these interviews include self-learning, self-authorship, engineering identity, and engineering belongingness.

These are preliminary results and much more in-depth investigation must be carried out before conclusive statements can be made about which constructs best describe the dynamics at play. A key limitation to this study is its reliance on scales with minimal numbers of items. Future work is suggested to take on the following steps: Narrative research approaches should be used more thoroughly, allowing for the students' voice to be the source of experiences and therefore constructs that are investigated further. Based on the constructs that emerge clearly, a robust survey using the full existing scales for those constructs should be designed. The survey should be deployed as part of an experiment with a control group designed within the course to attribute any change from this construct more conclusively.

The identification of a relevant construct or set of constructs to capture the African engineering students' experience holds potential for impacting how educators on the continent understand their students' needs and trajectories, thereby offering tools for providing more contextually-relevant teaching and learning experiences.

Acknowledgements

Thanks to Ashesi University's Provost's Office for supporting this work through the Faculty Research Impact and Excellence Grant and to the teaching team members who enabled these courses to succeed.

References

[1] H. R. Beem, "Exploring the Role of Project-based Learning in Building Self-efficacy in First-year African Engineering Students," *ASEE Annu. Conf. Expo. Conf. Proc.*, 2021.

[2] H. R. Beem, "The role of machine shop sessions in building confidence amongst first year engineering students in Ghana," *IEEE Glob. Eng. Educ. Conf. EDUCON*, pp. 1469–1474, 2021, doi: 10.1109/EDUCON46332.2021.9454012.

[3] H. Beem, "Exploring the role of the physical environment in building self-efficacy in first-year African engineering students," *ASEE Annu. Conf. Expo. Conf. Proc.*, 2022.

[4] U. Scholz, B. G. Doña, S. Sud, and R. Schwarzer, "Is general self-efficacy a universal construct? Psychometric findings from 25 countries," *Eur. J. Psychol. Assess.*, vol. 18, no. 3, pp. 242–251, 2002, doi: 10.1027//1015-5759.18.3.242.

[5] D. M. Williams and R. E. Rhodes, "The Confounded Self-Efficacy Construct: Review, Conceptual Analysis, and Recommendations for Future Research," *Health Psychol. Rev.*, vol. 10, no. 2, p. 113, Apr. 2016, doi: 10.1080/17437199.2014.941998.

[6] E. M. Dell, Y. Verhoeven, J. W. Christman, and R. D. Garrick, "Using Self-Determination Theory to build communities of support to aid in the retention of women in engineering," *Eur. J. Eng. Educ.*, vol. 43, no. 3, pp. 344–359, 2018, doi: 10.1080/03043797.2017.1410522.

[7] Ryan R. M. and Deci E. L., "Overview of Self-Determination Theory: An Organismic Dialectical Perspective," *Handb. Self-Determination Res.*, pp. 3–33, 2002.

[8] E. L. Deci and R. M. Ryan, "The 'what' and 'why' of goal pursuits: Human needs and the self-determination of behavior," *Psychol. Inq.*, vol. 11, no. 4, pp. 227–268, 2000, doi: 10.1207/S15327965PLI1104_01.

[9] J. Martin, "Self-regulated learning, social cognitive theory, and agency," *Educ. Psychol.*, vol. 39, no. 2, pp. 135–145, 2004, doi: 10.1207/s15326985ep3902_4.

[10] A. Bandura, "Social cognitive theory: an agentic perspective," *Annu. Rev. Psychol.*, vol. 52, pp. 1–26, 2001, doi: 10.1146/annurev.psych.52.1.1

[11]. A. Bandura, "Self-efficacy," In V. S. Ramachaudran (Ed.), Encyclopedia of Human Behavior, vol. 4, pp. 71-81, New York: Academic Press, 1994.

[12] J. Code, "Agency for Learning: Intention, Motivation, Self-Efficacy and Self-Regulation," *Front. Educ.*, vol. 5, pp. 1–15, 2020, doi: 10.3389/feduc.2020.00019.