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Advancing Transformative and Sustainable STEAM Education through Bootcamps: Assessing Higher Education Students' Knowledge of 21st-Century Competencies for Career Success

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Abstract

This study sought to examine how STEAM bootcamps foster transformative and sustainable STEAM education by assessing higher education students' general knowledge of 21st-century competencies provided through STEAM-focused bootcamps for career success. A cross-sectional research design was adopted for the study. Two research questions guided the study. A 12-Bootcamps Knowledge Items (BKIs) questionnaire titled: Questionnaire on Advancing Transformative and Sustainable STEAM Education through STEAM-Focused Bootcamps (QATSSESFB) was used to elicit data from 79 tertiary students through social media and email. The instrument was subjected to face validation by three experts. Descriptive statistics (mean and SD), t-test, and ANOVA were used to analyze the data collected, with internal consistency of 0.96 (Cronbach's alpha). Descriptive statistics were used to answer the RQ1, while t-test and ANOVA were used to answer RQ2. Results revealed strong knowledge (M = 3.96, SD = 1.14), with all BKIs scoring above the 2.50 threshold, indicating high knowledge of competencies like digital literacy, problem-solving, and communication. No significant differences were found across gender (p = 0.834), programme of study (p = 0.070), age (p = 0.360), or place of residence (p = 0.654), suggesting uniform knowledge possibly facilitated by Information and Communication Technology (ICT). These findings highlight bootcamps' role in fostering inclusive, transformative education through innovative online and hybrid delivery. Hence, aligning with the 4th (Quality Education) and 8th (Decent Work and Economic Growth) Sustainable Development Goals (SDGs). The study concluded with the recommendation that bootcamp access should be scaled and their models integrated in formal curricula.

Keywords: STEAM Education, Bootcamp, Knowledge Assessment, Sustainable Transformation, Career Success, 21-Century Competencies

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Introductions

The COVID-19 pandemic has profoundly underscored the critical role of Science, Technology, Engineering, Arts, and Mathematics (STEAM) education in preparing higher education students with knowledge of 21st-century competencies required to navigate dynamic labor markets. The global health crisis accelerated digital transformation across industries, from remote work to e-commerce, thereby, exposing vulnerabilities in traditional education systems that prioritize rote learning over practical, adaptable skills. In Nigeria, where youth unemployment rates exceed 30% and skill mismatches hinder economic growth (International Labour Organization, 2023), STEAM education emerges as a vital solution. By integrating interdisciplinary approaches, STEAM fosters innovation, problem-solving, and creativity. It equips students with knowledge of necessary competencies required to address real-world challenges such as climate change, digital inequality, and economic disruption. This form of education not only builds technical proficiency but also encourages collaboration and lifelong learning, essential for thriving in a global economy increasingly driven by artificial intelligence and automation (Stauffer, 2022; Slyter, 2019). Understanding these competencies is the foundation for career readiness. STEAM-focused initiatives (particularly informal programs like bootcamps) offer innovative pathways to equip students with knowledge of these essential competencies.

Competency refers to a set of measurable attributes; including knowledge, skills, and attitudes; essential for successful performance (Ibezim & Chukwujekwu, 2017). Knowledge of appropriate competencies gives higher education students a competitive edge by enhancing their ability to secure high-quality, well-paid jobs, improve job performance, advance in their careers, and sustain employment. 21st-century competencies, by extension, are set of state-of-the-art competencies; including learning skills (such as critical thinking, problem-solving), literacy skills (such as digital and information literacy), and life skills (such as collaboration, adaptability); necessary for career success in today's dynamic labor markets. In Nigeria, where the digital economy is expanding but access to training is limited, these competencies are crucial for reducing unemployment and promoting economic inclusion among higher education students. Lack of these competencies contributes to skill gaps, hence, leaving graduates unprepared for jobs in emerging sectors like fintech, renewable energy, and data science (Kenan Insight, 2023). This raises the question of how students acquire familiarity with these competencies, which this study conceptualizes as knowledge.

In this study, knowledge refers to students' self-reported familiarity with and recognition of 21st-century competencies and the features of STEAM bootcamps that foster them, as measured by a 5-point Likert scale ranging from "Very Unknowledgeable" to "Very Knowledgeable." This definition declarative emphasized knowledge as understanding and awareness of concepts, rather than procedural knowledge or skill demonstration. Such knowledge serves as a foundational step toward engagement with learning opportunities, additionally, it influences students' motivation to pursue competency-building programs. In educational research, self-reported knowledge is a valid indicator of cognitive readiness, particularly in cross-sectional studies exploring perceptions in underserved populations (Wahono & Chang, 2019). For Nigerian higher education students, this knowledge can bridge the gap between theoretical learning and practical application, ultimately supporting long-term professional growth and career success.

Career success in the contemporary context extends beyond securing employment to include sustained professional growth, adaptability to change, and contribution to economic development.

It involves creating entrepreneurial opportunities, advancing in roles, achieving financial stability, and maintaining job security amid disruptions like automation and economic shifts (Ibezim & Chukwujekwu, 2017). In Nigeria, career success is challenged by high graduate unemployment and underemployment, where many qualified individuals settle for low-quality jobs lacking security or growth potential (International Labour Organization, 2023). Knowledge of 21st-century competencies enhances career success by improving employability, performance, and resilience. Hence, enabling individuals to transition between roles, innovate, and contribute to national productivity. Career success is particularly relevant in developing economies, where aligning education with labor market needs is critical for reducing poverty and achieving sustainable growth, hence, making STEAM education a key enabler.

STEAM education integrates Science, Technology, Engineering, Arts, and Mathematics to promote interdisciplinary learning, creativity, and real-world problem-solving. By incorporating the arts into traditional STEM disciplines, STEAM fosters holistic development, innovation, and the ability to address complex societal challenges through design thinking and creative expression (Camp Finder, 2018; Lavner Camps, 2025). In Nigeria, STEAM education can empower students to tackle local issues like sustainable energy and digital inclusion, thereby, preparing them for global competitiveness. This interdisciplinary approach not only enhances technical skills but also cultivates empathy and cultural awareness which is essential for collaborative environments. As formal education systems often fall short in delivering these integrated experiences, informal programs like bootcamps have emerged as effective supplements.

Bootcamps are intensive, career-focused educational programs delivered online or in-person, covering areas such as programming, graphic design, robotics, animation, and ubiquitous computing. They augment formal education by fostering knowledge of 21st-century competencies essential for occupational success, including digital literacy, problem-solving, creativity, collaboration, and adaptability (Camp Finder, 2018; Lavner Camps, 2025). Unlike traditional curricula, which often prioritize theoretical knowledge, bootcamps emphasize hands-on, project-based learning in condensed timeframes; and enable students to rapidly acquire practical understanding of skills demanded by today's employers (Stauffer, 2022). In contexts like Nigeria, where formal education may not keep pace with industry demands, bootcamps offer accessible pathways to competency development, particularly through online platforms that reach rural and underserved populations (Mead, 2018; STEAM Ahead, 2025). STEAM-focused bootcamps, in particular, integrate Science, Technology, Engineering, Arts, and Mathematics to promote interdisciplinary thinking and innovation. Hence, addressing the urgent need to prepare a workforce equipped to navigate a fast-paced, technology-driven world while promoting transformative and sustainable education.

Transformative STEAM education refers to innovative, solution-based learning that fosters interdisciplinary competencies that can fundamentally disrupt students' global perceptions, behaviors, and capabilities, so as to drive personal and societal change. It goes beyond knowledge transmission to foster critical consciousness, equity, and innovation, encouraging learners to question assumptions and apply learning to real-world problems (Our Kids, 2023). STEAM bootcamps are designed to provide, deepen, and strengthen transformative STEAM education that equips higher education students with knowledge of the broad spectrum of 21st-century competencies essential for career success in today's dynamic labor markets. They deepen higher education students' knowledge of critical thinking, creativity, resilience, digital literacy, and social skills (such as teamwork, communication) (Our Kids, 2023). Through features like hands-on

coding, small class sizes, and project presentations; bootcamps foster knowledge of competencies like problem-solving, teamwork, and communication. By providing inclusive and scalable learning opportunities, often via online or hybrid formats, bootcamps address educational gaps in resource-constrained regions like Nigeria. They aid in combating summer learning loss (Mead, 2018; Cooper, n.d.; Destination Science, n.d.), empower underrepresented groups, including young women (U.S. Department of State, 2017), and reduce STEAM gender disparities. Furthermore, bootcamps are ideal vehicle for driving the 4th (Quality Education) and 8th (Decent Work and Economic Growth) Sustainable Development Goals (SDGs); Hence, preparing students for sustainable careers and flattening the global economic and social effects of weak workforce. In STEAM bootcamps, transformation occurs through interdisciplinary projects, collaborative environments, and exposure to diverse ideas. Hence, shifting students from passive recipients to active creators. For higher education students in Nigeria, transformative education through bootcamps can challenge systemic barriers, promote social mobility, and cultivate visionary leaders capable of driving national development, while ensuring long-term sustainability.

Sustainable education prioritizes long-term, equitable, and environmentally conscious learning models that endure beyond short-term interventions. It emphasizes scalability, inclusivity, and alignment with global goals, such as SDGs 4 (inclusive and equitable quality education) and 8 (decent work and economic growth). Sustainable education ensures access for marginalized groups, minimizes resource waste, and prepares learners for future challenges (U.S. Department of State, 2017). STEAM bootcamps exemplify sustainability through low-cost, replicable formats (e.g., online delivery) that reach rural and underserved populations, hence reducing educational inequalities while building competencies for green jobs and economic resilience in Nigeria. This sustainability complements transformation, and creates lasting impact on career success.

However, rapid technological advancements continually deskill workforces, requiring reskilling or upskilling to keep pace. While future technologies and required skills are unpredictable, knowledge of 21st-century competencies, such as adaptability and collaboration, enables students to master technical skills across disciplines. Additionally, rising global unemployment and the gig economy's growth; accelerated by the COVID-19 lockdown; have raised doubts about whether higher education students are knowledgeable of these competencies (International Labour Organization, 2023; Kenan Insight, 2023). Labor market disparities; labor shortages in high-income countries and job scarcity elsewhere; highlight the need for higher education students to understand the role of bootcamps in fostering career-relevant competencies. Many workers risk settling for low-quality, poorly paid jobs due to limited knowledge of these skills. These underscores the urgent to assess the competencies taught at schools, specifically, at tertiary level. Hence, these backdrops spur the researchers to assesses higher education students' general knowledge of 21st-century competencies offered through STEAM-focused bootcamps, with the aim of addressing the gap in understanding how such programs prepare students for sustainable career success in dynamic labour markets.

Statement of the Problem

Despite the growing recognition of 21st-century competencies as essential for career success in a rapidly evolving, technology-driven global economy, significant gaps persist in higher education systems, particularly in developing countries like Nigeria. Traditional formal education often fails to adequately equip students with knowledge of practical, interdisciplinary skills such as digital

literacy, critical thinking, collaboration, and creativity, leading to skill mismatches, high youth unemployment, and labour market disparities (International Labour Organization, 2023; Kenan Insight, 2023). The COVID-19 pandemic further exposed these deficiencies by accelerating digital transformation and remote work, while informal learning opportunities, such as STEAM-focused bootcamps, remain underutilised due to limited knowledge among students of their benefits. In Nigeria, where access to quality education is constrained by resource limitations, infrastructure challenges, and socio-economic inequalities, many higher education students may lack knowledge of how innovative programs like bootcamps can bridge these gaps, empower underrepresented groups, and foster sustainable career pathways. Moreover, it is unclear whether knowledge such competencies varies across socio-demographic factors (e.g., gender, programme of study, age, place of residence), potentially perpetuating inequities. This knowledge gap hinders the effective integration of transformative, solution-based educational models needed to achieve Sustainable Development Goals 4 (Quality Education) and 8 (Decent Work and Economic Growth). Hence, these backdrops spur the researchers to assesses higher education students' general knowledge of 21st-century competencies offered through STEAM-focused bootcamps, with the aim of addressing the gap in understanding how such programs prepare students for sustainable career success in dynamic labor markets.

Purpose of the Study

This study aimed at assessing higher education students' knowledge of 21st-century competencies provided through STEAM-focused bootcamps and their relevance for career success in Nigeria. Specifically, the study sought to:

i. Determine the extent to which higher education students knowledgeable of the 21st-century competencies provided through STEAM-focused bootcamps for career success.
ii. Examine whether higher education students' knowledge of the 21st-century competencies provided through STEAM-focused bootcamps for career success vary across socio-demographic characteristics.

Research Questions

1. To what extent are higher education students knowledgeable of the 21st-century competencies provided through STEAM-focused bootcamps for career success?
2. How does higher education students' knowledge of the 21st-century competencies provided through STEAM-focused bootcamps for career success vary across socio-demographic characteristics?

Methodology

This study employed a cross-sectional research design to assess higher education students' general knowledge of 21st-century competencies offered through STEAM-focused bootcamps for career success. A self-made structured questionnaire titled: "Questionnaire on Advancing Transformative and Sustainable STEAM Education through STEAM-Focused Bootcamps (QATSSESFB)" was developed using Google Forms, and was distributed nationwide via social media platforms (Facebook, Twitter, WhatsApp) and email. The instrument was used to elicit the opinion of 79 higher education students in Nigeria. The online distribution targeted students with general knowledge of STEAM-focused bootcamps; hence; reflecting an innovative, cost-effective, and scalable method, while supporting sustainable research practices in resource-constrained settings

like Nigeria. The questionnaire comprised two sections: Part I collected socio-demographic characteristics and Part II included 12 Bootcamps Knowledge Items (BKIs) assessing knowledge of STEAM bootcamps' features and their role in fostering 21st-century competencies. Responses indicated strong awareness across all 12 BKIs (M = 3.96, SD = 1.14), with no significant differences across socio-demographic characteristics ($p > 0.05$), hence, supporting inclusive education models.

The questionnaire underwent face validation by three experts: two from university lecturers and one STEAM bootcamp instructor. Response options were Very Knowledgeable (VK, 5), Knowledgeable (K, 4), Neutral (N, 3), Slightly Unknowledgeable (SU, 2), and Very Unknowledgeable (VU, 1). Cronbach's Alpha was used to determine the internal consistency of the items in the instrument and a reliability coefficient of 0.96 was obtained, indicating excellent internal consistency (George & Mallery, 2003). Data were analyzed using SPSS version 23. Mean and Standard Deviation (SD) were calculated to address the first research question, with a mean score of 2.50 as the threshold for acceptable knowledge level, representing the midpoint of the 5-point Likert scale. Independent t-tests and ANOVA were conducted at a 0.05 significance level to examine variations in knowledge across socio-demographic characteristics (gender, programme of study, age, place of residence), with p-values < 0.05 considered statistically significant. T-tests assessed differences by gender, while ANOVA examined variations across programme of study, age groups, and place of residence

Results

Research Question 1

To what extent are higher education students aware of the 21st-century competencies provided at STEAM-focused bootcamps for transformative career success?

Table 1. Mean Ratings and Standard Deviations of Higher Education Students' Knowledge of 21st-Century Competencies Provided Through STEAM-Focused Bootcamps for Career Success.

Item No	Bootcamps Knowledge Items Bootcamps are designed to:	Mean	SD	Remark
1.	deliver after-school STEAM courses to foster awareness of interdisciplinary competencies, such as problem-solving and digital literacy, for career readiness.	3.97	1.20	**K**
2.	maintain low student-to-instructor ratios to promote collaborative learning and personalized feedback so as to enhance teamwork and communication skills.	3.49	1.14	**K**
3.	ensure inclusive engagement and fostering creativity and self-directed learning among students by offering personalized learning experiences tailored to diverse interests.	4.06	1.18	**K**

4.	cultivate creativity and technical proficiency among students by encouraging them to develop innovative projects, such as games, apps, and robots.	4.13	1.14	**K**
5.	provide hands-on training in cutting-edge fields like coding, AI, robotics, artistry, and cybersecurity, in order to enhance digital literacy and problem-solving skills.	4.15	1.15	**K**
6.	foster critical thinking and motivation by employing interactive and engaging teaching methods to make STEAM concepts accessible.	4.14	1.11	**K**
7.	nurture students' confidence, motivation, and self-awareness through project-based learning so as to support lifelong learning and adaptability.	4.01	1.16	**K**
8.	deliver intensive, accelerated training to equip students with career-relevant skills in a short timeframe, promoting agility and employability.	3.99	1.16	**K**
9.	offer flexible, hybrid (online and in-person) courses to ensure accessibility and inclusivity, supporting scalable education models.	3.77	1.10	**K**
10.	integrate computer-based learning with regular breaks and supplementary activities to enhance engagement and information retention.	3.79	1.10	**K**
11.	provide opportunities for students to showcase projects through weekly presentations, hence, fostering communication and leadership skills.	4.05	1.13	**K**
12.	simplify complex STEAM concepts through innovative pedagogies, thereby, making them accessible to higher education students and enhancing critical thinking.	4.01	1.09	**K**
	Cluster Values	**3.96**	**1.14**	**K**

Key: SD = Standard Deviation, K = Knowledgeable

The results presented in Table 1 revealed strong knowledge across all BKIs, with all BKIs exceeding the 2.50 threshold, labeled as "Knowledgeable". Individual means ranged from 3.49 to 4.15, reflecting high knowledge of competencies like problem-solving, digital literacy, and communication. with standard deviation between 1.09 to 1.20. A cluster mean of 3.96 indicated that, generally, higher education students are knowledgeable about the 21st-century competencies provided through STEAM bootcamps for career success. The cluster standard deviation of 1.14 shows that the opinions of higher education students about the 21st-century competencies provided through STEAM bootcamps for career success are almost the same.

Research Question 2

How do higher education students' knowledge of the 21st-century competencies provided through STEAM-focused bootcamps for career success vary across socio-demographic characteristics?

To address Research Question 2, t-tests and ANOVA were conducted to examine variations in knowledge of 21st-century competencies provided through STEAM bootcamps across socio-demographic characteristics (N = 79). Table 2 presents the t-test results for gender, while Tables 3, 4, and 5 summarize ANOVA results for programme of study, age, and place of residence, respectively. No significant differences were found across gender ($t(77) = 0.211$, $p = 0.834$), programme of study ($F(5, 73) = 2.143$, $p = 0.070$), age ($F(7, 71) = 1.121$, $p = 0.360$), or place of residence ($F(2, 76) = 0.427$, $p = 0.654$). These findings suggest consistent knowledge of bootcamps' features (such as hands-on coding, project presentations) and associated competencies (such as digital literacy, communication) across diverse student groups, hence, supporting inclusive and scalable education models aligned with SDG 4 (Quality Education).

Table 2. t-test Analysis of the Differences Between the Mean Responses of Male and Female Higher Education Students on their Knowledge about the 21st-Century Competencies provided through STEAM-Focused Bootcamps for Career Success.

Gender	N	Mean	Std. Deviation	T	Df	Sig.	Remark
Male	46	3.9815	0.87796	0.211	77	0.834	NS
Female	33	3.9345	1.10106				

Key: N = Distribution, Sig. = p-value, NS = Not Significant

The result Table 2 showed that the independent samples, between male and female students' t-test analysis of means failed to reveal a reliable influence of students' gender on their knowledge of the 21st-century competencies provided through bootcamps for career success. That is to say that the difference between the mean responses of male and female students on their knowledge of the 21st-century competencies provided through bootcamps for career success is not statistically significantly different from zero at the 5% level of significance. Consequently, it was not possible to reject the null hypothesis with a $t_{(cal.)} = 0.21$ at 77 degree of freedom and a p-value = 0.83 which was greater than the 0.05 level of significance. Additionally, the evidence ($p = 0.83$) provided is sufficient to suggest that students' gender did not statistically significantly influence their knowledge of the 21st-century competencies provided through bootcamps for career success. Hence, the inference drawn was that the mean ratings of the opinions of male and female students on their knowledge of the 21st-century competencies provided through bootcamps for career success did not differ statistically significantly.

Table 3. Summary of ANOVA Analysis of the Responses of Students of National Diploma, Higher National Diploma, National Certificate in Education, Undergraduate/Bachelor's Degree, Masters, Doctorate, and others on their knowledge about the 21st-Century Competencies provided through STEAM-Focused Bootcamps for Career Success.

	Sum of Squares	df	Mean Square	F	Sig.	Remark
Between Groups	9.410	5	1.882	2.143	0.070	NS
Within Groups	64.114	73	0.878			
Total	73.5240	75				

Key: F = Calculated Value

The result on Table 3 showed that the one-way, among-programme of study analysis of variance failed to reveal a reliable influence of students' programme of study on their knowledge of the 21st-century competencies provided through bootcamps for career success. It was possible to upheld the null hypothesis with a $F_{(5, 73)} = 2.143$ and a p-value = 0.070 which was greater than the 0.05 level of significance. Though, there is insufficient evidence (p = 0.070) to suggest that students' programme of study did not statistically significantly influence their knowledge of the 21st-century competencies provided through bootcamps for career success, the inference drawn was that students studying higher national diploma, national certificate in education, undergraduate/bachelor's degree, masters, doctorate, and others did not differ statistically significantly in their opinion about their knowledge of the 21st-century competencies provided through bootcamps for career success.

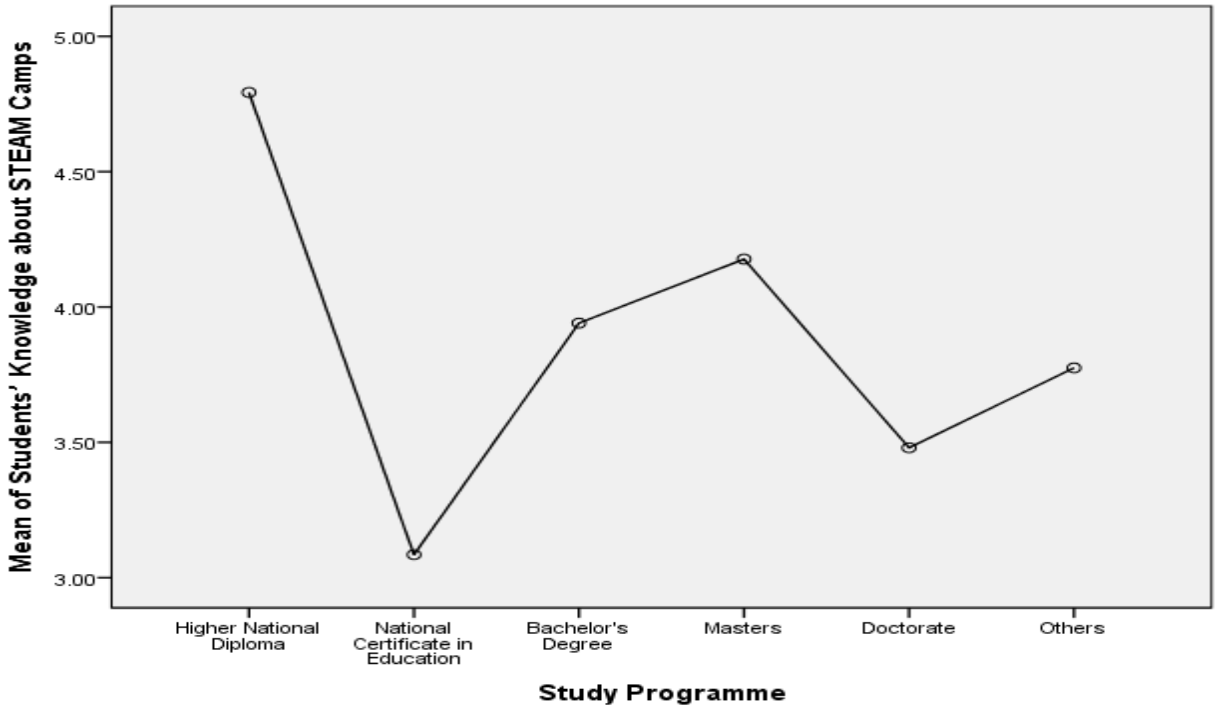

Figure 1: Means of Students' Knowledge Against their Programmes of Study

Moreover, fig.1 showed that there is no correlation between knowledge and programme of study.

Table 4. Summary of ANOVA Analysis of the Responses of Higher Education Students with Ages ranging from 15-19, 20-24, 25-29, 30-34, 35-39, 40-44, 45-49, and 50+ on their knowledge about the 21st-Century Competencies provided through STEAM-Focused Bootcamps for Career Success.

	Sum of Squares	df	Mean Square	F	Sig.	Remark
Between Groups	7.316	7	1.045			
Within Groups	66.207	71	0.932	1.121	0.360	NS
Total	73.524	78				

Result on Table 4 showed that the one-way, among-age analysis of variance failed to reveal a reliable influence of students' ages on their knowledge of the 21st-century competencies provided

through bootcamps for career success. It was not possible to reject the null hypothesis with a $F_{(7, 71)} = 1.121$ and a p-value = 0.360 which was greater than the 0.05 level of significance. The evidence (p = 0.360) provided is sufficient to suggest that students' ages statistically significantly did not influence their knowledge of the 21st-century competencies provided through bootcamps for career success. Hence, the inference drawn was that the mean ratings of the opinions of students with ages ranging from 15-19, 20-24, 25-29, 30-34, 35-39, 40-44, 45-49, and 50+ on their knowledge of the 21st-century competencies provided through bootcamps are statistically significantly the same for career success.

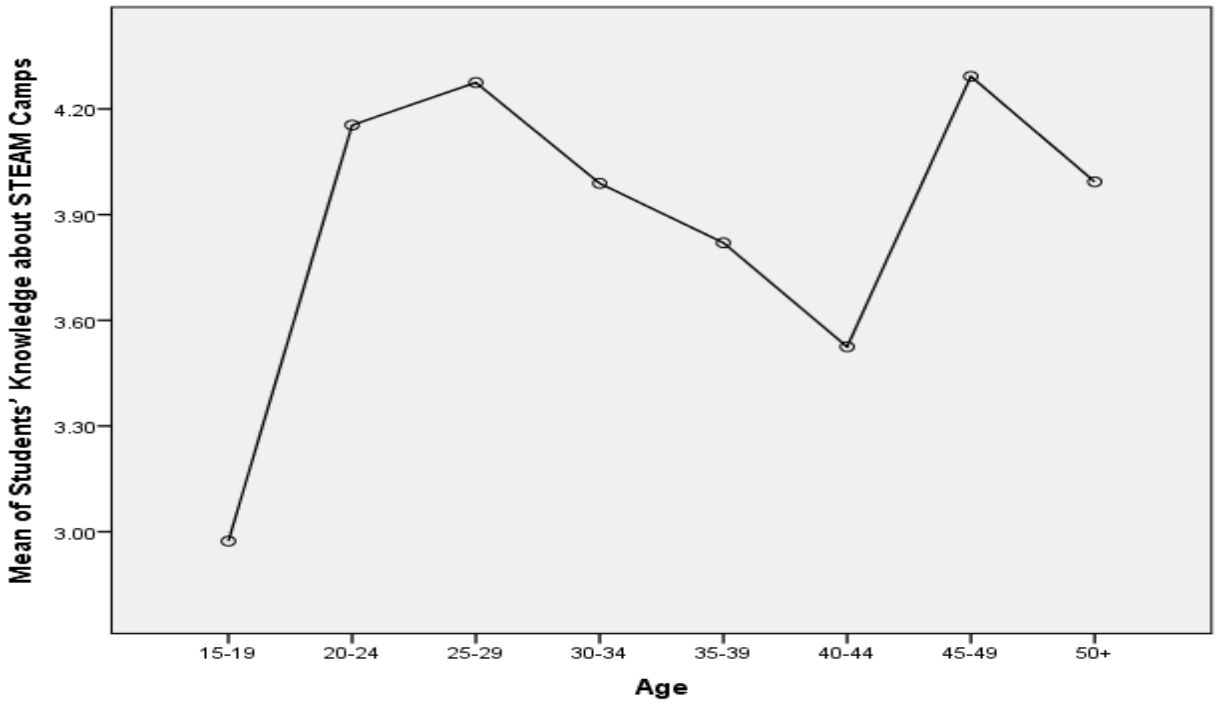

Figure 2: Means of Students' Knowledge Against their Ages

Moreover, fig.2 revealed that there is no correlation between knowledge and ages.

Table 5. Summary of ANOVA Analysis of the Responses of Higher Education Students residing in Urban Area, Suburban Area, and Rural Area on their knowledge about the 21st-Century Competencies provided through STEAM-Focused Bootcamps for Career Success.

	Sum of Squares	df	Mean Square	F	Sig.	Remark
Between Groups	0.817	2	0.408			
Within Groups	72.707	76	0.957	0.427	0.654	NS
Total	73.524	78				

Result on Table 5 showed that the one-way, among-place of residence analysis of variance failed to reveal a reliable influence of higher education students' place of residence on their knowledge of the 21st-century competencies provided through bootcamps for career success. It was possible to upheld the null hypothesis with a $F_{(2, 76)} = 0.427$ and a p-value = 0.654 which was greater than the 0.05 level of significance. The evidence (p = 0.654) provided is sufficient to suggest that students' place of residence did not statistically significantly influence their knowledge of the 21st-

century competencies provided through bootcamps for career success. Hence, the inference drawn was that statistically significant difference did not exist among the mean ratings of the responses of higher education students residing in urban area, suburban area, and rural area on their knowledge of the 21st-century competencies provided through bootcamps for career success.

Figure 3: Means of Students' Knowledge Against their Places of Residence

Moreover, fig.3 showed that there is no correlation between knowledge and place of residence.

Discussion

Knowledge of Competencies

This study assessed higher education students' general knowledge of 21st-century competencies provided through STEAM-focused bootcamps, revealing strong knowledge across 12 Bootcamps Knowledge Items (BKIs) (M = 3.96, SD = 1.14) among 79 Nigerian students. All BKIs scored above the 2.50 threshold (means 3.49–4.15), indicating high knowledgeable ("K") of innovative features like hands-on coding (M = 4.15), project presentations (M = 4.05), and personalized learning (M = 4.06), which foster competencies such as digital literacy, communication, and creativity. The online and hybrid delivery of STEAM-focused bootcamps; scalable through Nigeria's growing ICT infrastructure; enhances accessibility and aligns with innovative, solution-based education for transformative and sustainable development (Lavner Camps, 2025). This knowledge suggests students recognize bootcamps' value in addressing community needs, particularly in resource-constrained settings.

High knowledge implies that promoting engagement with STEAM bootcamps could bridge Nigeria's labor demand-supply disparities, reduce deskilling, and minimize reliance on low-quality

jobs, hence, fostering a competent workforce (SDG 8) (STEAM Ahead, 2025). STEAM-focused bootcamps also address formal education gaps, mitigate summer learning loss, empower underrepresented groups (such as young women), and reduce STEAM gender disparities (SDG 4) (Stauffer, 2022). For example, online STEAM camps, such as those offered by Lavner Camps (2025), integrate virtual reality and cybersecurity, reflecting innovative pedagogies adaptable to Nigeria. These findings corroborate with Ibezim and Chukwujekwu (2017), who noted that competencies enhance job creation and career sustainability. This finding is also in consonance with Denson et al. (2015), who found STEAM camps improve STEM knowledge. Stauffer (2022) and Slyter (2019) emphasize that 21st-century competencies enable students to thrive in dynamic labor markets.

The findings corroborate Kney et al. (2016), who bridged STEAM learning loss through camps, and Hayden et al. (2011), who reported improved performance through STEAM programs. These outcomes also align with the opinions of Meyers et al. (2013), Popovic and Lederman (2015), and the National Research Council (2009) who highlight that informal STEAM settings, including online platforms, enhance STEM interest and complement formal education (Lavner Camps, 2025).

Socio-Demographic Variations

This study also analyzed four factors (socio-demographic characteristics of the respondents) assumed to influence higher education students' knowledge about the 21st- century competencies provided at bootcamps for transformative career success: 1) gender, 2) study programme, 3) age, and 4) place of residence. The statistical analysis of students' responses on these showed that higher education students' gender, study programmes, ages, and places of residence did not statistically significantly influence their knowledge of the 21st-century competencies provided through bootcamps for career success. This implied that there were no bootcamps knowledge differences among the higher education students irrespective of their socio-demographics characteristics: gender ($t(77) = 0.211$, $p = 0.834$), programme of study ($F(5, 73) = 2.143$, $p = 0.070$), age ($F(7, 71) = 1.121$, $p = 0.360$), or place of residence ($F(2, 76) = 0.427$, $p = 0.654$). Table 3 shows varied means by programme (for instance, Higher National Diploma: $M = 4.79$; National Certificate in Education: $M = 3.09$), but the marginal p-value (0.070) suggests insufficient evidence for differences. Table 4 indicates higher knowledge in ages 25–29 ($M = 4.28$) and 45–49 ($M = 4.29$), and Table 5 shows rural residents ($M = 4.23$) with slightly higher knowledge than urban ($M = 3.99$) or suburban ($M = 3.82$), yet no differences were significant. This uniformity, driven by ICT-enabled access to online bootcamp information (Camp Finder, 2018; U.S. Department of State, 2017), supports inclusive education models (SDG 4) (Ibezim & Chukwujekwu, 2017).

The lack of gender differences corresponds with Wahono and Chang (2019) and Maltese and Cooper (2017), who noted equal STEAM knowledge opportunities across genders. This finding also strengthens that of Rocker Yoel and Dori (2022) who found gender differences in STEM exposure, however, both studies focused on different contexts. While Rocker Yoel and Dori (2022)'s was on knowledge application while the present study was on knowledge possession.

Going by the study outcome based on the higher education students' programme of study, there is a discrepancy between the findings of the present study and that of Popovic and Lederman (2015) and Blotnicky et al. (2018) who found statistically significant difference in the mean ratings of participants on their knowledge about STEAM based on their educational status. The discrepancy could be as result of the classifications used in the different studies, however, the evidence ($p =$

0.070) provided by the present study is insufficient to conclude that students' programmes of study did not statistically significantly influence their knowledge of the 21st-century competencies provided through bootcamps for career success. Additionally, the duo found positive correlation between the knowledge possessed and the educational status of the participants (knowledge possession are higher in the higher educational status group) while the present found no correlation between programme of study and knowledge (fig. 1).

Similar to other findings, the ages of the participants could not influence their opinions on their knowledge of the 21st- century competencies provided at bootcamps for transformative career success. This finding disagrees with that of Gonzalez-Herrera et al. (2022), Aljefree et al. (2023), Hasan et al. (2023), and Ahmed et al. (2023), who observed statistically significant difference in the mean ratings of participants across their ages. This dissonance in age could be attributed to the classifications used and differing knowledge contexts. While the former study was on health knowledge, the present study was on bootcamps knowledge. Additionally, [23] found positive correlation between the knowledge possessed and the ages of the participants (knowledge possession are higher in the older age group) while the present found zero correlation between the knowledge possessed and the ages of the participants (fig. 2).

Finally, the outcome of this study based on the higher education students' places of residence harmonizes that of Gözüm et al. (2022) whose study could not establish a statistically significant difference in the mean STEMPCK scores of the participating countries, hence, suggesting broad STEAM knowledge access via online platforms (Lavner Camps, 2025). Albeit, classification on Gözüm et al. (2022) study was based on countries, the present study was based on nature of the place of residence such as urban, suburban, and rural area (fig. 3).

Conclusion

Technological advancements reshape labor markets, making 21st-century competencies (such as digital literacy, critical thinking, collaboration) essential for higher education students. This nationwide study of 79 Nigerian higher education students found strong general knowledge ($M = 3.96$, $SD = 1.14$) of these competencies through STEAM-focused bootcamps, facilitated by innovative online and hybrid delivery models (Lavner Camps, 2025). The study found no significant differences across gender, programme of study, age, or place of residence ($p > 0.05$). These findings indicate uniform knowledge which was possibly driven by Nigeria's ICT infrastructure, hence, aligning with SDG 4 (Quality Education) (Camp Finder, 2018). This knowledge underscores bootcamps' potential to reduce labor disparities, deskilling, and low-quality employment (SDG 8) while bridging formal educational gaps and empowering underrepresented groups (SDG 4) (STEAM Ahead, 2025; Stauffer, 2022).

Recommendations for Further Studies

To maximize bootcamps' impact,

- the Nigerian Ministry of Education and universities should partner with STEAM providers to expand online and hybrid programs, particularly in rural areas where knowledge is high ($M = 4.23$) (Lavner Camps, 2025).
- formal curricula should adopt bootcamp methods (such as hands-on coding, virtual reality projects) to reinforce competencies (Mead, 2018).

- public-private partnerships, like Michigan's STEAM Ahead program (2025), should fund internships to enhance workforce readiness (SDG 8).
- future research should use longitudinal designs to assess whether knowledge translates to participation and skill acquisition, with focus on specific bootcamp types (such as coding, robotics).
- larger samples should be studied in order to clarify marginal findings (for instance, p = 0.070 for programme of study) and explore regional variations within Nigeria.
- free online bootcamps could further democratize access, hence, supporting SDG 4.

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