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DESIGN, DEVELOPMENT AND TESTING OF A SCIENCE, TECHNOLOGY, ENGINEERING, ART AND MATHEMATICS EDUCATION LOCALISED CYCLE CAR MODEL: A CASE IN KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

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ABSTRACT

This study explores the integration of traditional craftsmanship, technology, and sustainable practices in STEAM education, focusing on the design, development, and testing of a cycle car at Kwame Nkrumah University of Science and Technology (KNUST). It addresses the gap in effective modelling of STEAM competencies in Ghanaian education. Through a mixed methods approach, the study assesses students' perceived usefulness and ease of use of the cycle car, highlighting the importance of a comprehensive education in preparing students for engineering tasks. The qualitative phase involves observations and interviews, while the quantitative phase uses surveys to measure the project's impact on innovation, problem-solving, and teamwork using the Technology Acceptance Model. Findings reveal a significant link between educational experiences and practical abilities, demonstrating the effectiveness of integrating art with science and math in STEAM education. Over 90% of respondents expressed high satisfaction with the cycle car, underscoring its potential as a viable alternative to traditional mobility methods. The study validates the knowledge and skills acquired by students, emphasising the practical application of these talents in real-world projects.

Keywords: STEAM, biomorphism, interdisciplinary, perceived ease of use, perceived use.

INTRODUCTION

The study is rooted in a passion for exploring the convergence of traditional craftsmanship, technology, and sustainable practices. The desire to bridge the gap between theoretical understanding and practical application has been a driving force. Despite the global recognition of the importance of STEAM education and the potential benefits of integrating STEAM competencies into hands-on projects like cycle car production, there is a lack of specific knowledge about the effective modelling of these competencies within the Ghanaian educational context. The article, STEAM education: student learning and transferable skills by Namukasa (2020), largely examines the design and execution of STEAM programs that emphasise character development and academic abilities through engaging assignments and realistic experiences. The highlighted requirement for future study is a lack of investigation into the efficiency of modelling STEAM-related competences, notably through a cycle car technology in Ghanaian higher educational environments. This topic contributes to the current literature by offering actual data and insights on how practical, multidisciplinary projects can bridge theoretical knowledge with real-world applications, therefore improving overall skill development. On the other hand, the paper, A Study on the Impact of STEAM Education for Sustainable Development Courses and Its Effects on Student Motivation and Learning by Su (2021) also investigates how learning outcomes and students' readiness for sustained learning are affected when STEAM is included in interactive media. It especially looks at whether, following an intense VR encounter, pupils are more eager to learn about their traditional culture. The dearth of empirical evidence on how real-world STEAM projects, like cycle cars, might improve learning outcomes and promote sustainable learning in the context of Ghanaian higher education has been recognised as a research gap that needs to be filled. This gap exists due to the focus on individualistic learning, undefined student skills, and limited transferability of knowledge across technologies, leading to reduced productivity and a focus on repair over innovation. The results of this study have shed light on how successful these kinds of multidisciplinary, practical applications are. Understanding how to optimise the cycle car production process for STEAM competency development is crucial for addressing the specific educational needs and challenges in Ghana and ensuring that students are adequately prepared for the demands of a rapidly evolving technological landscape. The inclusion of art in the original STEM framework can enhance learning in more integrated and comprehensive ways by helping students to adopt systematic thinking techniques employed by both scientists and engineers and artists and designers (Bazler & Van Sickle, 2017).

The goal of this research is to build and create a functioning cycle car model and assess its perceived usefulness and ease of usage among students at Kwame Nkrumah University of Science and Technology. This study aims to give insights into excellent STEAM education approaches and their practical use in higher education settings.

METHODOLOGY

This research is Mixed Method (Sequential Exploratory). The study aimed to provide a comprehensive understanding of how the integration of STEAM-related competencies through the construction and fabrication of a cycle car. The study aims to explore the impact of this project-based learning experience on students' innovation, problem-solving skills, and teamwork. The first phase of the study involves a qualitative data collection, including observations and interviews, to explore students' experiences and perceptions of the cycle car project. This qualitative phase provided insights into the factors that contribute to the development of STEAM competencies in students. The interview was divided into three main sections, each exploring different aspects of creating a cycle car using local materials and STEAM competencies. Local Material Selection: The first part of the interview focused on selecting available and reusable local materials, chosen for their adaptability and creative potential. Muniru, a dealer of new engine parts, suggested components such as a Haojin 110cc engine, which he affirmed could power the vehicle effectively, citing its common use in rural motorcycles carrying loads up to 20 times their weight. Samuel, another interviewee, listed materials like automatic and manual window gears, boot lock systems, plastic bumpers, and side mirrors. He emphasized these items' availability and modifiability, making them suitable for the vehicle's design. STEAM Competency Analysis: The second section analysed students' STEAM-related skills, particularly those gained from their courses that directly support cycle car production. Respondents acknowledged that their academic backgrounds provided knowledge in construction techniques, material processing, and effective communication strategies. These skills are essential for tasks like material selection, cutting, molding, and integration, all of which are pivotal in the cycle car's development. Optimising STEAM Integration: In the final section, the study looked at integrating STEAM competencies to enhance the vehicle's design and function. Interviewees detailed how their coursework in areas like material integration, sustainable design, and automotive engineering contributes to the project. Knowledge of applied mathematics and data-driven design also supports optimizing performance and efficiency. Respondents emphasised that this holistic integration of STEAM skills is crucial for creating a cycle car that balances performance, safety, and environmental friendliness. The study then proceeds to the quantitative phase, where surveys or assessments were used to measure the Perceived Use and Perceived ease of Use of the cycle car project on 132 students from various STEAM related backgrounds namely Art, Engineering and Sciences. The sampled population was 7 students from the Art, Engineering and Sciences, 4 experts in mechanical, electrical, welding and fabrication. The sampling was random and purposive, respectively.

The Design Process

Based on the data collected, the design process ensued with a series of sketches. The creative process involved conceptualising features inspired by the eagle, depicted in the sketch drawing shown in Figure 1, and integrating them into the design of the car's front. Elements such as the eyes, beak, and head of the eagle were carefully considered during this phase. The propulsion system of the cycle vehicles relies on chain-driven backwards and forward gears, along with shaft and chain-driven wheels, to generate power. Each wheel of the car is equipped with independent suspension to enhance stability and maneuverability. The mounting point for both the steering bar and the front wheel, supported by the double wishbone suspension, is strategically positioned. Additionally, a cylindrical coil spring device serves as the shock absorber at the back of the vehicle.

The concept generation through Biomorphism.

The figures below show the pencil morphed process of the animals into the vehicle.

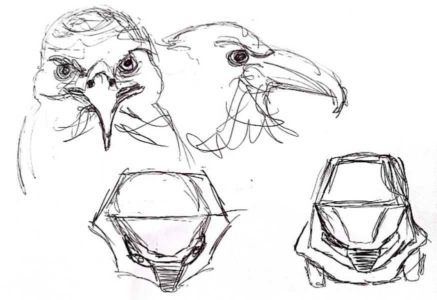

Fig 1: The view of the car mimicking the eagle's head

Fig 2: The side view of the car with the king fisher

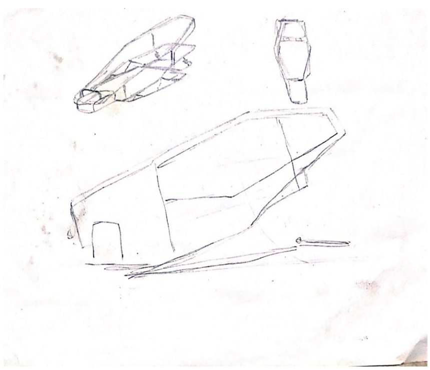

Fig 3: The skeletal side view

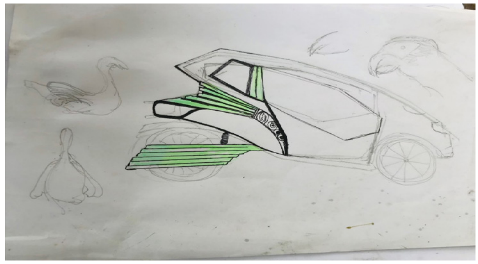

Fig 4: The side view of the car

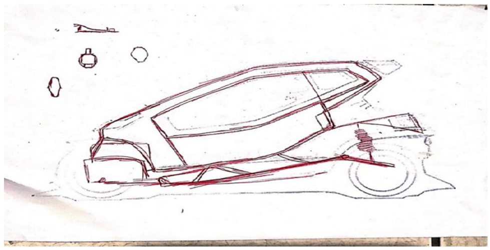

Fig 5: The framed view with mechanism

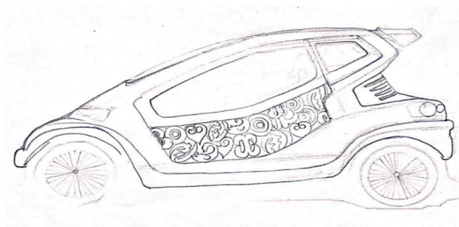

Fig 6: The side view of the development

The vehicle parts were modelled using CorelDraw and Rhinoceros 3D. In a collaborative effort, the individual components of the four-wheeled vehicle were assembled using appropriate joints. This process emphasised the importance of critical thinking in visualising the size and form of the design. Artistic design principles were crucial at this stage as they formed the foundation for achieving a realistic simulation. Simple geometric shapes such as squares, ovals, rectangles, freehand lines, and fill tools in CorelDRAW were used to create the shapes.

Fig 7: The view of a king fisher bird

Fig 8: The face the Eagle

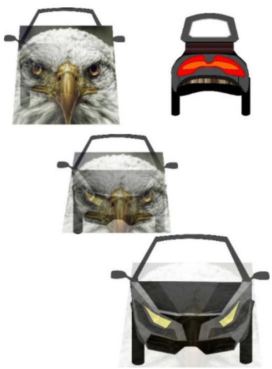

Fig 9: 2D morphed front

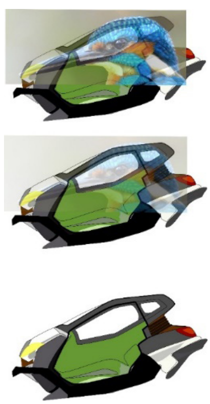

Fig 10. The side view

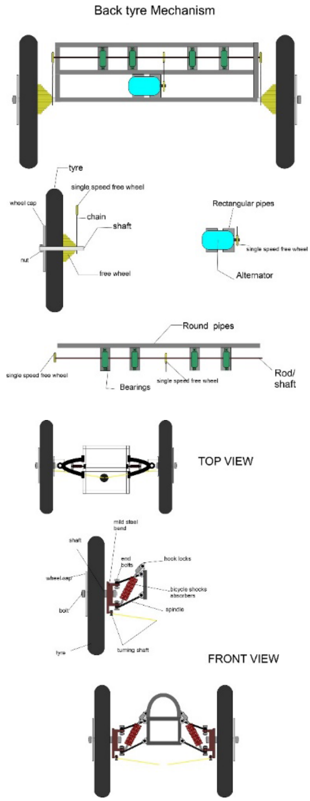

Fig 11: The CorelDraw renditions of the Mechanisms (both images)

The rear shaft system, shown in Figure 11, includes gears and bearings to facilitate tire rotation. The front suspension system, illustrated in Figure 11, features shock absorbers with a modified motorcycle stand serving as the suspension arms. This arrangement helps mitigate the torque experienced by the car on various road surfaces.

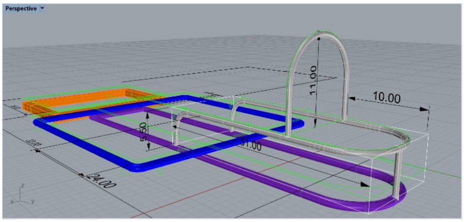

Fig 12: The 3D modeling of the chassis to scale

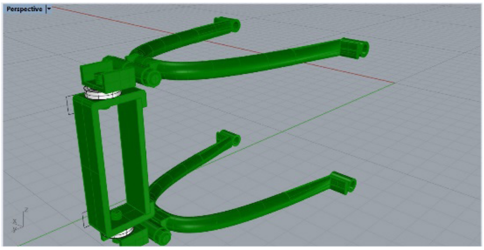

Fig 13: The 3D view of the Wishbone suspension

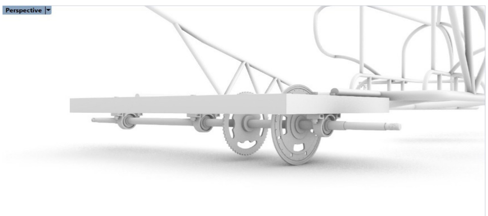

Fig 14: A 3D view of the Back shaft and brake system

The 3D model was meticulously crafted to showcase all the intricate details, including the size and thickness of the front suspension (Figure 13). Each wheel of the vehicle has independent suspension, and the size of the structural pipes for the chassis was also determined. The bends in the pipes and the welds at the different joints were accurately represented using the 3D software.

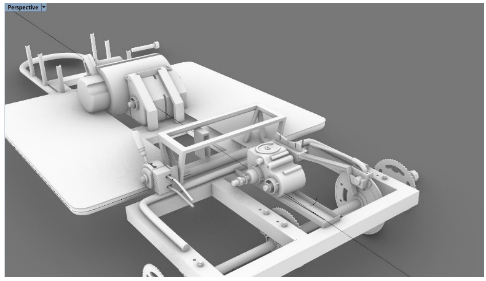

Fig 15: A 3D view of the chassis with the Powertrain

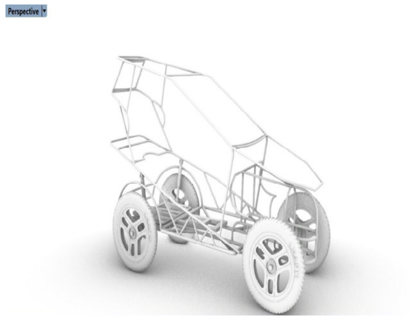

Fig 16: A 3D view of the Frame work

Fig 17: A 3D view of the Covering the sheet

The Development Stage

This process consists of the different procedures carried out during the working process.

Working procedures of chassis

Working process (exploded view of chassis)

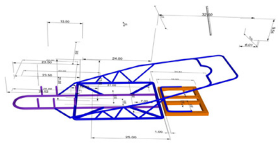

Fig 18: Exploded of chassis

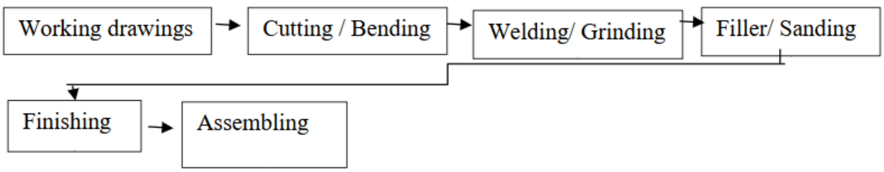

Fig 19: The project employed a six-step approach as illustrated in figure

The metal pipes were measured, cut, and bent using a mechanised bending machine with a crosscutter, following the working drawing. Excess material was trimmed after bending, and each part, including the back turning frame, sitting area, and front frame chassis, was fully welded. Pivots were added between the back shaft frame and the sitting area for back suspension. The front frame chassis was measured for the installation of the wishbone suspension, and connectors were welded to join the seating area to the front and back, facilitating the back suspension.

Fig 20: Measuring and cutting of the frame

Fig 21: Mechanized bending

Fig 22: The welded chassis frame

Fig 23: The assembled frame

Working Process (suspensions, steer rack, seat)

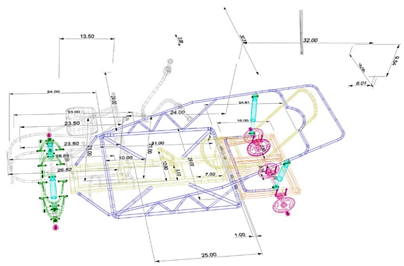

Fig 24: Exploded of suspensions, steer rack, seat

PROCEDURES

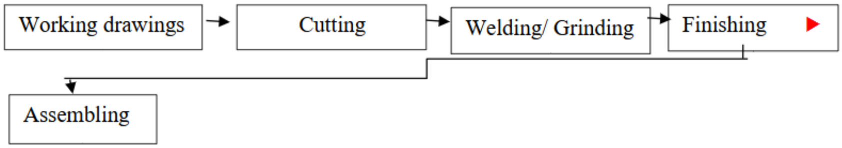

Fig 25: The project employed a Five-step approach as illustrated in this figure

Motorcycle stands were used to form the wishbone suspension, with pivots added to facilitate rotation. The shaft holder was fabricated with a 'U' galvanised iron, bearings were fixed, and the assembly was secured with bolts, nuts, welding, and grinding. The wishbone was adjusted using a levelled wall and then transferred to the mainframe. The back frame was fabricated with shocks positioned between the pivoted back shaft frame and the front frame, secured with bushings, bolts, and nuts. The steer rack was made using bicycle forks, steel pipes, car links, and a motorcycle handlebar, all positioned and braced on the frame. The seat frame was fabricated from round pipes and angle iron, padded with high-density foam, and supported by plywood.

Fig 26: A pivoting mechanism fixed for movement

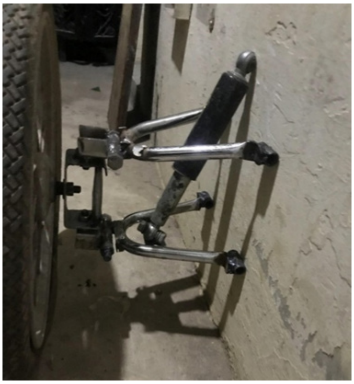

Fig 27: Taking the suspension Alignment measurement.

Fig 28: A view of the fixed back suspension

Fig 29: A view of the complete steer rack

Fig30: Covering the high density with the wrapping foam

seat)

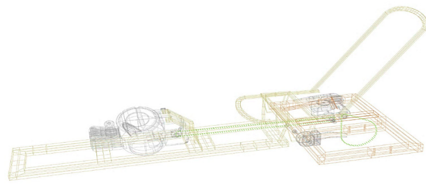

Fig 31: Exploded of Transmission and Engine seat

Working Process (Transmission and Engine)

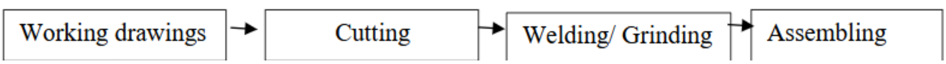

Fig 32: The project employed a Four-step approach as illustrated in this figure

The transmission system of this vehicle employed the chain transmission. The motorcycle engine was employed. A seat area was created with angle bar to accommodate the engine. In creating an effective chain transmission, chain tensioners were also fabricated with sprockets, bolts and springs and were fixed at the points closer to the driven gear. This is to prevent the chain from easily coming off. The transmission system also came with a reverse gear that was built to support the motorcycle engine to utilise the chain to reverse. This gear was built using 4mm plate, sprockets and bearings. However, a forward and reverse gear was bought for an effective movement.

Fig 33: The engine seat area

Fig 34: The fixed engine

Fig 35: The shaft system with the break disc

Working Process (Frame work of body and sheet covering)

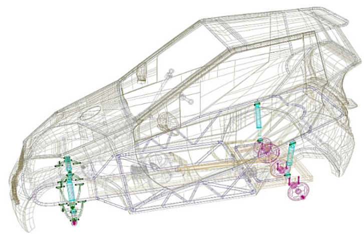

Fig 36. Exploded of Frame work of body and sheet covering

Procedures

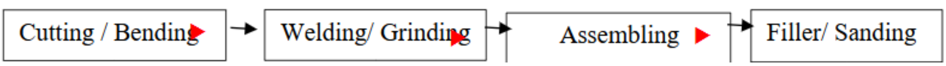

Fig 37: The project employed a Four-step approach as illustrated in this figure

The framework involved bending and cutting ¾ inch round pipes. The framing was done in stages: ceiling to the side, then the bonnet and bumper, followed by the back and interior framing, using welding and fasteners for joining. For sheet forming, 1mm galvanised sheets were shaped using cardboard templates to avoid excess, with folding, welding, and screwing techniques. Molding chisels, ball peen hammers, and mallets were used on wood surfaces, employing repoussé and chasing techniques for intricate parts like the bonnet. Adinkra designs were incorporated into the sheet forming process. Simple chasers were used to create the designs, which were drawn onto the metal surface, fastened to soft wood, and chased and outlined. These designs were featured on the vehicle's door area.

Fig 38: Full welding

Fig 39: View of the finished frame work

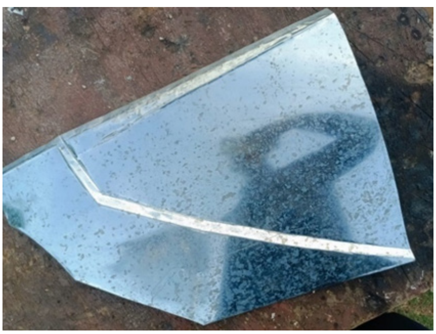

Fig 40: View of the chased do sheet

Fig 41: A view of the back

Fig 42: A view of the fixed repousse work

Working Process

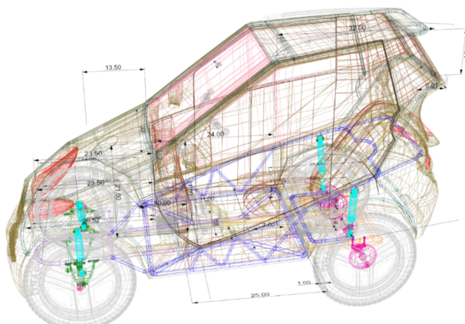

Fig 43: Exploded of Accessories (Bumper), window fixing, door accessories etc

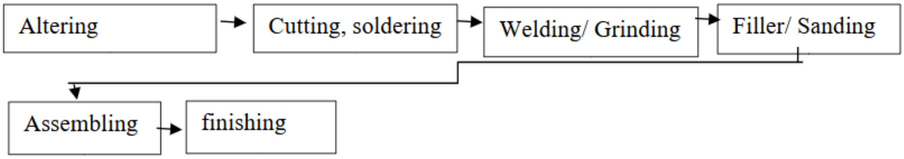

Fig 44: The project employed a six-step approach as illustrated in this figure

A Picanto bumper was cut and joined with a soldering iron, screws, and fibre filler for reinforcement. An old Elantra bumper was cut, joined with screws and resin, sanded, and filled. Holes were created in the back bumper for reverse parking sensors, and wheel caps were fixed using screws. The top railing was made from bent round pipes with washers and bolts welded into place and attached to redwood ends. Plastic from rubber bowls was used for side fender designs, cut, trimmed, and screwed for aesthetics. The charging unit was housed in a wooden case. The automatic window gear was installed and connected on the driver's side. Fibreglass was shaped using a heat gun for the windows. Labels and logos were designed in CorelDraw, cut from aluminum and copper, and attached using Bostic glue. A Hyundai side mirror was modified, cut, welded, and fastened to the vehicle with final adjustments using Bonner.

Fig 45: A view of complete bumper

Fig 46: A view of the dried resin for the front bumper

Fig47: A view of the back bumper

Fig 48: A bent view of the pipe for railing

Fig 49: A view of the fixed railings

Fig 50: The pierced work fixed to the wood

Fig 51: The logo attached to the car

Fig 52: A wooden laser printed details of the vehicle

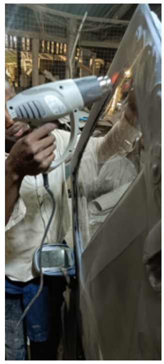

Fig 53: Using the heat gun to bend the fibre glass to conform to the shape of the door

Fig 54: A view of the Fixed side mirror

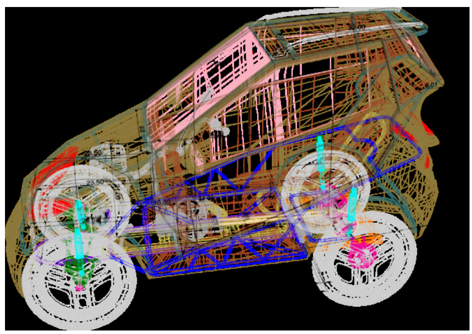

Fig 55: Exploded of Finishing process

PROCEDURES

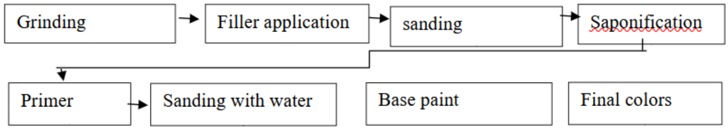

Fig 56: The project employed an Eight-step approach as illustrated in Fig 56

Surface Preparation: Saponification using soap, water, and a brush was performed to remove grease and oils from metal and tires. Red oxide was applied to prevent rust on iron parts, and etch primer was sprayed on the framework to enhance paint adhesion.

Fig 57: Saponification

Fig 58: Application of red oxide onto all iron part

Fig 59: Views of the sprayed frame

Filler Application and Sanding: Fibre filler and car putty filler were used to smooth sheet work edges. The filler was applied, then sanded to the desired smoothness with sandpapers, followed by final sanding with water and emery papers to prepare for spraying.

Fig 60: Applying fiber filler

Fig 61: Applied filler on the side of the vehicle

Fig 62: A second coat of primer

Painting and Finishing: Etch primer was sprayed on galvanized sheets and sanded, followed by car primer in multiple coats. The final coat was sanded with water for a smooth finish. After the final paint was applied, patterns were sprayed using different colors. Epoxy resin was mixed and applied to wooden parts to preserve them against outdoor conditions.

Fig 63: Preparation for painting

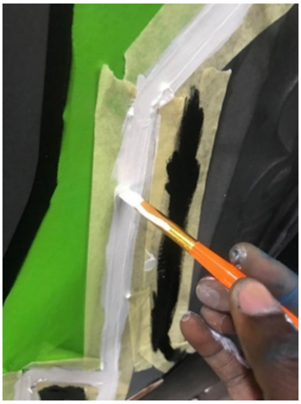

Fig 64: Painting some design shapes

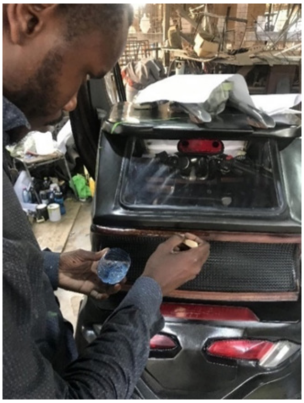

Fig 65: Applying the resin on the wooden part

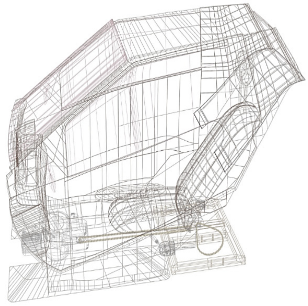

Fig 66: Exploded of Interior

Working Process (Interior)

Procedures

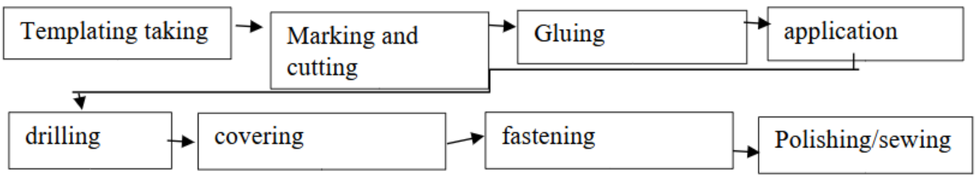

Fig 67: The project employed an Eight-step approach as illustrated in this figure

Templates of the inner parts were made using cardboard, transferred onto hard card, cut into shapes, and glued onto leather. The dashboard parts were cut, soldered together, and wrapped in black suede with glue. Wooden platforms with fasteners were used to hold the parts together.

Fig 68: The fixed dashboard and engine cover

Fig 69: The covered dashboard

Fig 70: Fixing the inner door handle to the foam board

The vehicle was tested by students from Kwame Nkrumah University of Science and Technology on the principal street of the campus.

Fig 71: Views of the testing at the Studio area

Fig 72: A night view testing

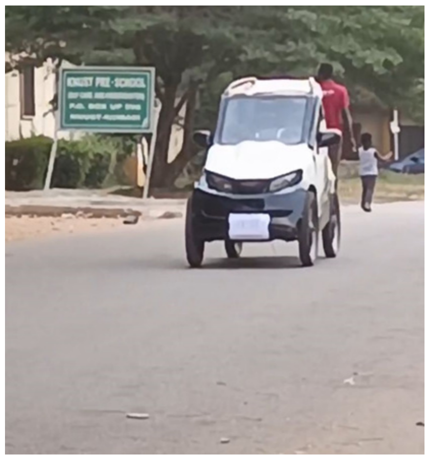

Fig 73: Testing on the Nursery school road

RESULTS AND DISCUSSION

Testing Perceived Use and Perceived Ease of use of the cycle car amongst the Population of the Kwame Nkrumah University of Science and Technology (The Qualitative phase)

The Results and discussions of the Technology Acceptance Model test

The graph below shows that ages 16 to 25 had the highest responds compared to the others. This is also evident as most of the undergraduate from the 1st to their final years are within the ages 16 to 25.

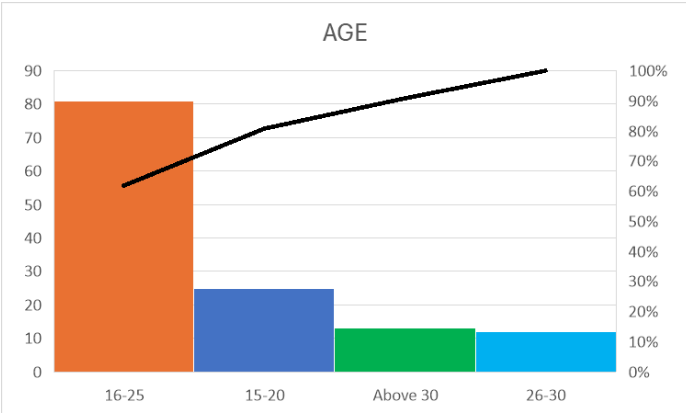

Fig 74: A demographic chart

The distribution of age and 'I found this product easy to use' showed the respondents extremely agreed with the vehicle and its movement as shown

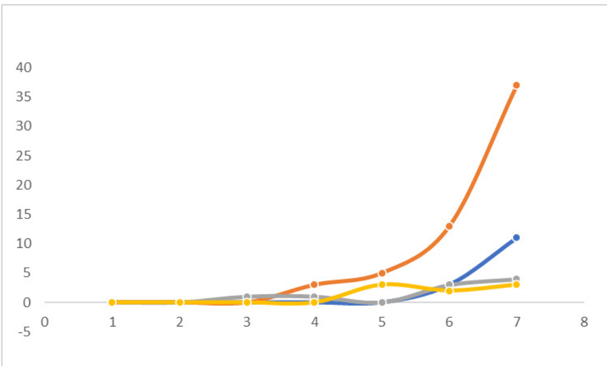

Fig 75: Distribution of Age and "I found this product easy to use."

Table 1: Scale Reliability Analysis

Scale	Mean	SD	Cronbach's α	McDonald's ω
	6.48	0.499	0.897	0.902

The means, standard deviations and frequency distributions for each construct (Perceived Usefulness and Perceived Ease of Use) were computed together. To assess the internal consistency reliability of the scale, Cronbach's alpha was calculated for each construct and the values were above 0.70, which is considered highly acceptable according to Nunnally's (1978) guidelines. Jamovi was used to perform both descriptive and reliability analysis. The mean score of 6.48 on the scale suggests that respondents gave the products excellent marks overall. The very low level of variability in the replies is indicated by the standard deviation of 0.499. Both McDonald's ω (0.902) and Cronbach's α (0.897) are higher than the generally recognised cutoff point of 0.70, demonstrating the scale's strong internal consistency. This indicates that the scale's elements are consistently assessing the same underlying concept.

The outcome of the test of the reliability analysis for the Correlation Matrix of the Constructs shows Pearson's r = 0.593. A relatively high positive correlation between perceived utility and ease of use is indicated by the symbol ***. This implies that users are more likely to find the cycle car beneficial if they find it straightforward to operate. The statistical significance of the finding (p-value <.001) indicates that the association is likely real and not the product of chance. Note: The degree of significance is indicated by the asterisks (***), where *** denotes a very significant result. An Independent Samples T-Test was done to determine whether there were any noteworthy variations; the average ratings on perceived utility and ease of use are compared. Statistic: This is the test's t-value. df: Sample size-related degrees of freedom. P-value: Indicates if there is a statistically significant difference between the groups.

College-specific Groups

The ease of use in the Art and Built Environment is 37.9, while the perceived utility is 38.6. In the Engineering field, the ease of use is 39.7, while the perceived usefulness is 40.1. In the Science, the mean perceived usefulness is 39.8, while the mean ease of use is 38.6. The mean for perceived utility and ease of use in social science and humanities is 40.0.

Groups according to Profession

KNUST Staff: 38.0 on the Ease-of-Use scale, and 37.1 on the perceived utility scale; Students: 38.5 on the ease-of-use scale, and 39.3 on the perceived usefulness scale

In conclusion, the Overall Satisfaction had almost 90% of respondents, across a wide range of demographics, say they are satisfied with using the cycle car on campuses or in gated communities. This high degree of satisfaction indicates that bicycle vehicles are well-liked and efficiently serve riders' demands. Efficiency and effectiveness also saw almost all respondents concur that the use of cycle vehicles increases the productivity, effectiveness, and efficiency of tasks. This suggests that for about a constrained neighborhood, the cycle car is a good substitute for more conventional forms of mobility like walking or public transportation. The Ease of Use and Learning Curve suggested that the majority of respondents indicated that riding the cycle car was easy to learn and operate, suggesting that the learning curve for these vehicles is not too steep. Encouraging widespread acceptance among users with different degrees of technical ability requires this simplicity of use. In its flexibility and adaptability, the cycle car was viewed by users as adaptable and simple to operate, indicating that it can suit a range of activities and user preferences in a gated community or campus setting. This flexibility is necessary to guarantee that the cycle car can successfully satisfy the requirements of various user groups. The demographic insights, although responses differ between age groups and genders, people's general opinion of the cycle car is still favourable. Due to their experience with and openness to new technology, younger respondents, especially the students, tend to indicate higher levels of agreement with the efficacy and utility of cycle cars.

The studies demonstrate the validity and reliability of the information and abilities students gain during their education at KNUST especially when collaborating with each other. It is confirmed by the high internal consistency values that the skills are taught and evaluated properly. Students' practical use of these abilities is demonstrated by the positive link found between perceived utility and ease of use, especially while operating a cycle car. The varied student body contributes a variety of experiences and viewpoints to the learning process, boosting the overall educational environment, according to significant links found between demographic characteristics and educational outcomes.

Furthermore, the thorough examination shows that the practical and cognitive abilities learned in the classroom are successfully applied in real world situations, as shown by the cycle car's efficient usage and perceived usefulness. This emphasises how crucial it is for Art, Engineering and Math students to have practical, hands-on learning experiences in order to ensure that they are ready for the workforce.

CONCLUSION

Ultimately, the innovative design of the cycle car, inspired by the aerodynamics of eagles and kingfishers, merges mechanical precision with natural artistic elements. Utilising advanced CAD programs such as CorelDRAW and Rhinoceros 3D, designers achieve high accuracy in prototypes through detailed simulations and efficient testing before manufacturing. This approach reduces costs and accelerates the design process, enabling effective comparison of different alternatives. The research underscored the significance of academic background, coursework, and hands-on experiences and ability to contribute to the cycle car development. A strong link between educational experiences and practical skills highlighted the importance of a comprehensive education in preparing students for engineering and design tasks. This expertise was applied in the project's design phase, incorporating biomorphism, computer-aided design, and vehicle dynamics modelling. Overall satisfaction with the cycle vehicle was high, with over 90% of respondents from diverse demographics expressing satisfaction with riding it on campus or in gated areas. This indicated that motorised vehicles effectively met users' needs and boosted productivity, efficiency, and effectiveness, making them a viable alternative to traditional mobility methods like walking or public transit. Demographic insights showed a positive perception of the cycle car, particularly among younger respondents familiar with new technologies. The study validated the knowledge and skills acquired by students at KNUST, confirmed by high internal consistency scores. The positive correlation between perceived usefulness and ease of use among students, especially while operating the cycle vehicle, emphasised their practical application of these talents. By integrating art with science and math, a comprehensive understanding of the interconnections between these fields emerged, demonstrating a holistic and multidisciplinary learning approach crucial for success in STEAM fields.

Fig 76: Back view of the actualized cycle car

Fig 77: Side View of the actualized car

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