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RENDERING INFRASTRUCTURE IN ANIMATION EDUCATION: A QUALITATIVE CASE STUDY OF SUSTAINABLE RENDER FARM IMPLEMENTATION AT THE UNIVERSITY OF EDUCATION, WINNEBA

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Abstract

The production of high-quality 3D animation requires substantial computational resources, particularly during the rendering phase, which is widely acknowledged as the most hardware-intensive stage of the digital animation pipeline. In many developing educational countries, including Ghana, tertiary institutions lack the high-performance computing infrastructure needed to support efficient rendering workflows. This study investigates the rendering challenges faced by Multimedia and Animation students in the Department of Graphic Design at the University of Education, Winneba (UEW), and examines the feasibility and benefits of establishing a departmental render farm to enhance animation education. Guided by a qualitative descriptive research design, the study gathered data from thirty-seven purposively selected students through semi-structured interviews. Thematic analysis was employed to explore their experiences, perceptions, and recommendations. Findings reveal significant limitations in students' rendering capacity, including extremely long rendering durations, overheating, noise generation, hardware breakdown, and failure to meet academic deadlines. Students rely solely on low-specification personal laptops, resulting in incomplete or low-quality rendering output and reduced creative experimentation. Although awareness of render farms varied, respondents unanimously emphasised the need for institutional rendering infrastructure. They proposed funding models such as departmental dues, university support, and private sector industry partnerships. The study concludes that, the absence of a render farm severely hampers teaching, learning, and creative productivity in animation-related courses. An ultramodern high performing render farm model that integrates on-premise CPU/GPU nodes is recommended as a scalable and cost-effective solution aligned with global best practices. Establishing a render farm at UEW would significantly improve students' technical competence, enhance the quality of academic outputs, strengthen interdisciplinary research, and position the university as a leader in digital creative arts education in Ghana.

This study contributes to the limited body of African scholarship on animation technology infrastructure and provides a practical framework for render farm adoption in higher education.

Keywords: *3D animation, rendering workflows, technical competence, multimedia, animation students, University of Education, Winneba, Ghana*

1. Introduction

The global animation industry has expanded significantly over the last three decades, driven by advancements in computer graphics, High-Performance Computing (HPC), and photorealistic rendering technologies. Rendering, which can be defined as the computational process that transforms three-dimensional models, lighting data, materials, textures and scene geometry into final still images or animation frames, is widely recognised as the most hardware-intensive stage of the 3D production pipeline. For instance, the work of Reinhard et al. (1998) notes that depending on scene complexity, rendering a single high-quality frame can take several hours or even days. With increasing adoption of Physically Based Rendering (PBR), ray tracing, global illumination, subsurface scattering, volumetric effects, and high-resolution formats such as 2K, 4K, and 8K, rendering demands continue to intensify (Zhang, 2024). These technological developments require institutions and studios to rely on more powerful computational infrastructures to maintain efficient production workflows.

In universities across Europe, North America, and Asia, render farms, thus high-performance computer clusters configured to distribute and accelerate rendering tasks, are standard components of animation, visual effects (VFX), and multimedia programmes. Render farms reduce rendering time, support iterative workflows and expose students to industry-standard production environments. In contrast, developing countries such as Ghana face considerable infrastructural limitations. At the University of Education, Winneba (UEW), Multimedia and Animation students rely heavily on low-specification personal laptops that are not optimised for rendering. Evidence from the researcher's earlier observations indicates that students experience a wide range of rendering-related challenges, including excessively long rendering times, overheating devices, noisy output, system crashes, and inability to submit assignments on time. These constraints diminish student productivity, limit creative expression, and negatively affect learning outcomes in animation-related courses. This study therefore aims to investigate these challenges in greater depth and propose a sustainable render farm implementation model suitable for UEW's technical and pedagogical context.

Despite the increasing relevance of 3D animation and the growing technological demands of rendering, the Department of Graphic Design at UEW lacks a dedicated rendering infrastructure capable of supporting efficient production workflows. Students rely solely on personal laptops with limited processing power, insufficient cooling systems, and inadequate graphics capabilities. The researcher's earlier observation confirms that many students endure unreasonably long rendering durations, often leaving their laptops running for several days to complete moderately complex scenes. Devices frequently overheat, shut down, or generate noisy and incomplete renders. As a result, students may submit assignments late or avoid exploring sophisticated visual techniques due to fear of rendering delays. The increasing adoption of computer-generated imagery (CGI), visual effects (VFX), architectural visualisation, virtual reality, and digital animation has substantially increased the computational demands of contemporary 3D production workflows. Rendering, which converts three-dimensional scenes into final images or animation sequences, has become one of the most computationally intensive stages of digital content creation. Consequently, higher education institutions that offer animation and digital media programmes increasingly rely on render farms to accelerate rendering, facilitate iterative experimentation, and expose students to industry-standard production environments.

While render farms have become an integral component of animation education and professional production pipelines in many universities and studios worldwide, similar computational infrastructure remains largely unavailable in many developing countries, including Ghana. At the University of Education, Winneba (UEW), students in the Animation and Multimedia programme depend almost entirely on personal laptops that possess limited processing capability, inadequate graphics performance, insufficient memory capacity, and poor thermal management for computationally demanding rendering tasks. These hardware limitations often result in prolonged rendering times, excessive overheating, system instability, noisy render outputs, interrupted workflows, and delayed submission of practical assignments. Such constraints not only reduce students' productivity but also discourage experimentation with advanced rendering techniques that are essential for developing professional competence in contemporary animation practice. Although numerous studies have investigated render farm architectures, distributed rendering systems, cloud computing, and high-performance computing within commercial animation and visual effects industries, relatively little empirical research has examined the implementation of render farms within higher education institutions in sub-Saharan Africa, particularly from the perspective of improving teaching, learning, and studio-based animation production. Consequently, there is limited contextual evidence to guide universities such as UEW in selecting a render farm model that is technically appropriate, financially sustainable, and pedagogically beneficial.

This study therefore addresses this gap by investigating the rendering challenges experienced by Multimedia and Animation students at the University of Education, Winneba, evaluating the educational implications of these challenges, and proposing a sustainable render farm implementation model that aligns with the University's infrastructural capacity, financial realities, and instructional objectives. The findings are expected to contribute to animation education by providing practical recommendations for strengthening digital production infrastructure and enhancing students' learning experiences within resource-constrained higher education environments. In this regard, the research sought to: 1. identify and analyse the rendering challenges experienced by students in the absence of a departmental render farm. 2. develop a sustainable and appropriate render farm implementation model suitable for UEW's environment, and 3. examine the academic, creative and institutional benefits associated with integrating a render farm into the department.

This study is momentous by examining the limitations associated with the absence of a dedicated render farm and proposing a sustainable implementation model; the study provides practical insights for improving rendering efficiency and studio-based production within the department. The findings will benefit students by identifying strategies for reducing rendering time, improving workflow efficiency, and enhancing access to computational resources required for high-quality 3D animation production. This is expected to strengthen students' practical competencies and support the successful execution of studio projects and academic assignments.

The study will also serve as a useful reference for lecturers responsible for teaching 3D animation and computer-generated imagery by providing evidence that can inform decisions regarding practical instruction, laboratory resource utilisation, and the integration of rendering technologies into studio-based teaching.

2. Review of Related Literature

2.1 Conceptualising Rendering in 3D Animation

Rendering is the computational process of converting three-dimensional (3D) digital scenes into final images or animation frames. This process simulates the behaviour of light, shadows, materials, and textures, using mathematical algorithms that calculate the interaction of virtual objects in a digital space (James et al., 1992). Modern rendering involves advanced methodologies such as Ray tracing, Path tracing, Photon mapping, Global illumination, Ambient occlusion, Subsurface scattering, Volumetric rendering, and denoising algorithms. Rendering quality depends on polygon density, resolution, anti-aliasing sampling, lighting complexity, and material sophistication. Higher precision and realism require exponentially greater processing power (Zhang, 2024). Also, 3D rendering uses specialist computer software to transform or generate a 3D model into a 2D image or animation (Autodesk, 2025). The rendering time of a 3D scene can take from 1 second to hundreds of days depending on the complexity of the scene. A scene with a simple lighting setup and geometry may take few seconds, while complex scenes packed with intricate objects, lights, high-resolution textures, dynamics, particles and simulations may take a very long time to render. It is only the hardware specifications of workstations and servers such as processor core count and speed, GPU core count and speed, and finally the memory size that can massively influence the rendering time. Technology has evolved and paved the way for rendering to be done by these main stream hardware, namely CPU-centered rendering software and GPU rendering cantered rendering (Alton, 2020).

Literally Central Processing Unit (CPU) is the computer's engine and rendering using this technology can be said to be the oldest since the advent of 3D animation whiles Graphic Processing Unit (GPU), on the other hand, can be said to take advantage of the Graphic Card's power to perform its kind of rendering. CPU rendering has been the oldest and for that matter, the best choice in the 3D animation and visual effects (VFX) industry. This has made it possible for most rendering software to be engineered and optimised to work seamlessly and efficiently with this computer hardware. This microprocessor technology has been the backbone of filmmakers and developers for decades to process complex graphics for CGI and VFX in movies, video games, among other media. Due to its heavy dependence on CPU power, it can seamlessly render very highly detailed and complex 3D scenes regardless of data size. CPUs have fewer core counts compared to GPUs and are slower because of their sequential processing capability, making the computer used for the rendering task have full access to the system memory and this greatly impacts the realism and details of geometry, no matter the intricacy of the 3D data (Render, 2025). The researcher can also contribute to this discussion by saying, CPU is also considered the heart of the computer, which is responsible for the flow of data and instructions to perform special tasks assigned to it.

The CPU is engineered on a core count structure, with modern processors having hyperthreading capabilities enabling them to split each physical processing core into two logical cores, also known as threads. Every CPU also has an embedded memory that makes it extremely fast in its computation as well as communicating with the other hardware on the motherboard. There are two main types of CPUs: x86/x64 and ARM. Though both perform fundamental functions, they have some differences that make each important over the other depending on what it is going to be used for. X86/x64 CPUs are designed for desktops, laptops, workstations and servers, while ARM CPUs are engineered for mobile phones and other devices that rely on microprocessors. There are two major types of CPUs, which are Intel Processors (i3, i5, i7, i9 and Xeon) and AMD Processors (Ryzen and Epyc) (Lenovo, 2025).

GPUs, on the other hand, have been a very fast, ever-evolving rendering technology that harnesses the power of the graphics processing unit and can render in real-time, making it ideal for architectural visualisation, virtual reality (VR) and video games. GPUs run in parallel with more core counts compared to CPUs but are clocked at a lower speed. They are also engineered not to easily overheat with stressful task therefore apt for 3D virtualisation, virtual reality, machine learning, interactive 3D rendering and game development as they are about 50 to 100 times faster than CPUs (Render, 2025). There are two major types of GPU brands, namely Nvidia and AMD. Nvidia (GeForce RTX for desktops and workstations, and Quadro for workstations and servers) uses the Cuda core technology (Nvidia, 2025), while AMD consists of Radeon RX for desktops and workstations as well as Radeon Pro for workstations and servers (AMD, 2025).

Again, more sophisticated setups such as network rendering or distributed rendering that spreads the rendering workload among high-specification networked computers can reduce the render time, greatly reducing the render time (Render, 2025; Autodesk, 2025). Endeshaw et al. (2024) further claim that, skills sets such as strong knowledge in 3D modeling using software like Maya, strong knowledge in rendering software such as Arnold or plugins such as V-Ray, good lighting skills, better texturing skills, ability to create great colour theme-composition and design principles, stronger control over the use of compositing and editing software such as Photoshop, Adobe After Effect and Adobe Premiere. Since the goal of this study is to achieve photorealistic 3D renderings, the researcher at this point is convinced to use the CPU approach because it does its computation sequentially and always guarantees realistic results. This can also be justified by the researcher as he embarked on an experimental project using a workstation desktop and server comprising the following specifications:

Workstation
Processor: Intel i7 6950X CPU, clocked at 3.00GHz base and 3.80GHz overclocked
10 Physical Cores and 20 Logical Threads with 25.0 MB L3 Cache memory
Single-socket processor
Memory: 32.0GB
Hard drive: 512 GB Intel M.2 running on Windows 10 Pro
2.7.2 Server
Processor: Intel Xeon E7-4860 V2 CPU, clocked at 2.60GHz base and 2.80GHz turbo clocked
12 Physical Cores and 24 Logical Threads with 30.0 MB L3 Cache memory
Quad socket configuration making 4 X 12 = 48 physical cores and 96 Logical Threads
Memory: 48.0GB
Hard drive: 160 GB Intel 2.5-inch SATA drive running on Windows Server 12 Pro

Figure 1 was what both were assigned to render in a networking configuration. The server, though with less clocked speed, outperforms the workstation with more overclocked CPU speed, making it convincingly clear that faster Maya-Arnold rendering primarily depends on core count. Thus, the more core counts a computer has, the faster the rendering time.

Figure 1: Image assigned to render in a networking configuration
Source: Researcher's database

The researcher noticed the server was 5 times faster than the workstation. This made the researcher convinced to settle on CPU rendering and also try to network available servers for this study.

The researcher noted that students understand rendering as the final process that "brings all elements together," consistent with global definitions, although most students lack exposure to optimisation techniques used in modern pipelines.

Figure 2: CPU rendering
Source: Researcher's database

2.2 Evolution and Importance of Render Farms

Render farms emerged in response to the exponential increase in rendering workloads during the rise of CGI animation in the 1990s. Early innovations documented by An et al. (2024) describe distributed rendering experiments that use networked desktop machines to divide rendering tasks. Render farms are indeed foundational to major animation studios, with concrete evidence demonstrating their critical infrastructure for high-performance computing in visual effects and animation. For Weta Digital, the render farm represents a massive computational resource consisting of over 80,000 CPU cores and GPU resources, requiring sophisticated custom queuing, scheduling, and job management systems (Wright & Diamond, 2014). Similarly, Pixar has developed Tractor, a comprehensive render farm monitoring system designed to manage complex rendering jobs across tens of thousands of cores (Wood-Gaines & Grant, 2015).

A render farm is defined as a collection of high-performance computers (nodes) connected through a network to process rendering jobs collaboratively (Pool, 2022). Render farms accelerate production timelines, reduce manual workload, and support studio-level CGI and VFX production. Key functions of render farms include:

- Distributing large render jobs across multiple machines
- Automatically queuing and prioritising tasks
- Monitoring node performance and usage
- Maximising efficiency through parallel processing

Render farms effectively reduce rendering time while maintaining visual quality through parallel computing and intelligent task distribution. Multiple studies demonstrate this capability (Yao et al., 2009). For instance, Huamani et al. (2019) implemented a render farm using 18 computers to process complex 360° models with 67 million pixels, significantly reducing processing time. Yao et al. (2009) developed a specialised render farm system with a "capacity-aware task scheduling strategy" that can dynamically assign tasks to optimise rendering speed. Importantly, researchers like Cater et al. (2003) have also shown techniques to maintain perceived visual quality during rendering, ensuring that computational efficiency doesn't compromise image perception. The evidence consistently shows render farms as a powerful solution for handling computationally intensive rendering tasks across various domains, from animation to scientific visualisation (Huamani et al., 2019).

2.3 Types of Render Farms

2.3.1 On-Premise Render Farms

On-premise render farms are indeed physically located within institutions or studios, consisting of interconnected workstations or servers through high-speed internal networks. Huamani et al. (2019), specifically describe render farms as "a set of computers interconnected by a high-speed network" designed to distribute computational tasks. Again, Patoli et al. (2009) provide concrete examples from university settings, demonstrating how institutions can leverage existing computer resources to create render farms. (Sheharyar & Bouhali, 2013), further confirms this model by discussing render farm implementation within university compute clusters. From the researcher's view, on-premise render farms have some advantages which include but not limited to, full control over security and data privacy, No recurring subscription fees and Consistent performance without Internet dependency. On the other hand, there are few disadvantages which includes: High upfront hardware cost, requires reliable electricity and cooling and needs skilled technical staff for maintenance.

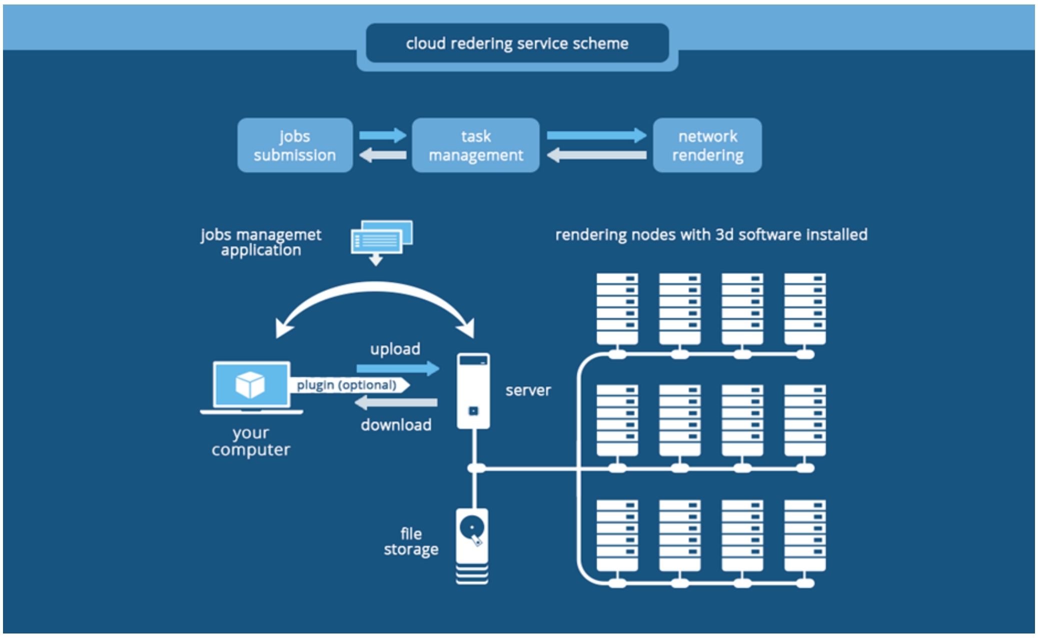

Figure 3: Cloud-based Rendering. GarageFarms (2022)

2.3.2 Cloud-Based Render Farms

Cloud render farms operate entirely online using remote servers, allowing users to submit rendering jobs via the internet without maintaining local rendering infrastructure. Commonly used commercial platforms include RebusFarm, Fox Renderfarm, GarageFarm, and RenderNow, which provide distributed computing resources optimised for 3D animation and visual effects rendering (RebusFarm, 2025); (Fox, 2025); (GarageFarm, 2025). Cloud-based rendering offers several advantages, including the elimination of hardware maintenance responsibilities, flexible pay-as-you-go pricing models, and the ability to scale computational resources on demand to meet high rendering workloads (Buyya et al., 2018). These features make cloud render farms particularly attractive for studios and independent artists with limited local computing capacity. However, cloud rendering also presents notable disadvantages. Rendering performance and job submission are highly dependent on stable and high-bandwidth internet connectivity; long-term or continuous usage may become costly compared to in-house solutions, and concerns remain regarding data security and intellectual property protection when production assets are processed on external servers (Zhang et al., 2010; Armbrust et al., 2010). Given UEW's inconsistent Internet reliability, cloud-based rendering may not be sustainable.

2.3.3 Hybrid Render Farms

Hybrid cloud rendering systems enable institutions to dynamically distribute computational workloads between local infrastructure and cloud resources, optimising rendering performance and capacity. Multiple studies validate this approach. Cho et al. (2014) demonstrated a hybrid render farm that extends local cluster rendering capacity through cloud-based servers. Also, Cachada et al. (2018) specifically showed this technique's effectiveness for complex CAD model rendering, achieving high frame rates even in constrained network environments. The key advantages include managing fluctuating rendering workloads, overcoming local infrastructure limitations, and providing flexible computational scaling. Ludlow et al. (2016) further confirmed the effectiveness of adaptive task allocation across local and remote cloud facilities. A concrete industry example comes from Isbella et al. (2022), where Weta FX used a hybrid cloud render-farm for the visually complex "Avatar: The Way of Water", successfully deploying scalable cloud resources to support intensive rendering requirements. For UEW, this model provides Local control, Lower cost, Flexibility during peak workloads, and Access to advanced GPU clusters when necessary. Hybrid farms are ideal for developing countries with unstable infrastructure.

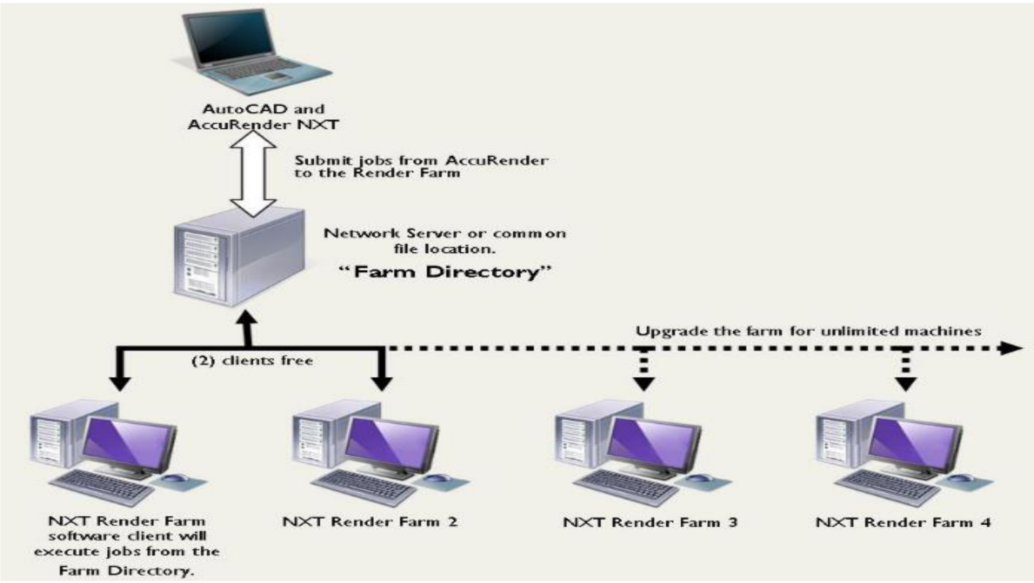

Figure 4: A Render Farm System.
Source: Field Research (2022)

2.4 Render Farm Architecture

2.4.1 Rendering Challenges in Resource-Constrained Educational Settings

Educational institutions across Ghana face systemic ICT limitations, including insufficient access to computers and other ICT infrastructure, restricted and uneven funding for digital infrastructure, slow or unreliable internet connectivity, and limited human-resource capacity for ICT support and maintenance (Mangesi, 2007; Yalley, 2022). In addition, unreliable electricity supply and power instability continue to undermine effective ICT use in schools, particularly where computer labs and digital learning depend on continuous power availability (Adarkwa, 2021; Baako et al., 2023). Collectively, these constraints reduce learners' and educators' ability to sustain high-demand software workflows and reliable access to digital production resources, thereby severely affecting 3D animation education, where photorealistic work requires stable electricity, capable machines, dependable connectivity, and consistent technical support (Mangesi, 2007). The researcher discovered that students often leave laptops rendering "overnight or for several days," resulting in poor performance and hardware damage. These findings align with global literature that emphasises high-performance computing as essential for digital learning (Nti, 2019; Wong, 2017).

2.4.2 Render Farms in Global Higher Education

Leading institutions such as Savannah College of Art & Design (SCAD), Vancouver Film School, Gnomon School of Visual Effects, University of Southern California, and Sheridan College. Moreover, these institutional render farms support Studio-level CGI production, High-resolution animation, Virtual and augmented reality, Motion capture and simulation and Visual effects pipelines (Kim & Park, 2020). Higher education institutions are increasingly utilising render farms to support advanced digital media production across multiple technological domains. While the sources provide limited direct confirmation for all listed institutions, there is substantive evidence of render farm implementation in academic settings. (Bartlett & Fu, 2022), specifically documents SCAD's advanced virtual production capabilities, including a 40'x20' LED volume set for real-time training. The work of Akihisa et al. (2007) demonstrates university-level render farm development for computer graphics courses, showing grid computing applications in academic environments. Similarly, Patoli et al. (2009) further validate the concept by proposing cost-effective render farm solutions for universities, highlighting how institutions can leverage existing computational resources. Aoki et al. (2017) also illustrate collaborative inter-institutional animation projects, suggesting render farm technologies support complex multimedia production. Unfortunately, UEW lacks similar infrastructure, which creates a competitive gap.

2.4.3 Relevance of Render Farms in Higher Education

Rendering is not merely a technical stage in the animation pipeline; it is a pedagogical process that supports students' understanding of light behaviour, digital cinematography, material simulation, and image formation. The rendering stage also enables students to evaluate, refine, and optimise their creative decisions through iterative experimentation. Integrating a render farm within a higher education context provides benefits such as improved output quality, exposure to industry-standard workflows, reduced hardware strain on personal devices, increased frequency of iterative learning cycles, support for complex assignments, and enabling interdisciplinary projects in VR, AR, and simulation. UEW as an academic community tends to benefit significantly from the render farm setup and these include higher-quality student work, faster assignment turnaround, improved iterative learning cycles, and enhanced understanding of rendering techniques.

3.0 METHODOLOGY

The study adopted a qualitative research approach that seeks to understand participants' experiences, perceptions, and interpretations of a phenomenon within its natural context rather than through numerical measurement (Creswell, 2013). The approach is particularly appropriate for studies investigating educational practices, technological challenges, and institutional experiences where detailed descriptions and contextual understanding are required. The present study sought to explore the rendering challenges encountered by Animation and Multimedia students during studio production, examine the implications of limited rendering infrastructure on practical learning, and identify participants' perspectives regarding the establishment of a departmental render farm. Because these issues are experiential and context-dependent, a qualitative approach was considered the most appropriate for achieving the objectives of the study.

The study employed a descriptive case study design. According to Yin (2018), a case study investigates a contemporary phenomenon within its real-life context, especially where the boundaries between the phenomenon and the context are not clearly distinguishable. The descriptive case study enables researchers to obtain an in-depth understanding of a particular institution, programme, or setting through multiple sources of evidence. The Department of Graphic Design at the University of Education, Winneba constituted the case for this investigation. The department offers specialised training in Animation and Multimedia where students undertake computationally intensive activities such as 3D modeling, texturing, lighting, animation, visual effects, and rendering. These practical activities provided an appropriate context for investigating rendering-related challenges and exploring the feasibility of implementing a departmental render farm.

The study was conducted within the Department of Graphic Design, University of Education, Winneba (UEW), Ghana. The department offers undergraduate programmes in Graphic Design, Advertising, Animation, and Multimedia. However, the study specifically focused on the Animation and Multimedia programme, where rendering forms an integral component of studio-based instruction and project production. Students within these specialisations routinely produce three-dimensional digital content requiring high computational power during rendering. Despite these computational demands, rendering activities are predominantly performed on students' personal computers, many of which possess limited processing capabilities. This makes the department an appropriate setting for investigating rendering constraints and assessing the need for centralised rendering infrastructure.

The participants comprised thirty-six (37) individuals drawn from the Department of Graphic Design. These included 35 undergraduate students enrolled in the Animation and Multimedia programmes as well as two (2) lecturers responsible for teaching Animation and Multimedia courses. The student participants were purposively selected from Levels 200, 300, and 400 because they had acquired sufficient practical experience in 3D modeling, lighting, rendering, and animation production to provide informed perspectives regarding rendering workflows and infrastructure limitations. The distribution of participants is presented in Table 1**.**

Table 1: Distribution of Participants

Academic Level	Multimedia	Animation	Total
Level 400	10	5	15
Level 300	5	5	10
Level 200	5	5	10
Lecturer	1	1	2
Total	**20**	**16**	**36**

Level 100 students were deliberately excluded because their curriculum primarily introduces the fundamental concepts of computer graphics and 3D animation. At this stage of their studies, students have limited exposure to advanced rendering workflows, computationally intensive studio projects, and rendering-related hardware constraints. Consequently, they were unlikely to provide sufficiently informed perspectives regarding the rendering challenges that constitute the focus of this study. The study employed purposive sampling because it enables researchers to deliberately select participants who possess specific knowledge and experience relevant to the research problem (Patton, 2015). This sampling strategy was considered appropriate because only students actively engaged in rendering-intensive coursework could provide meaningful insights into rendering workflows, computational limitations, and the practical implications of lacking a departmental render farm. Similarly, the lecturers' participant was purposively selected based on extensive teaching experience in Animation and Multimedia and direct involvement in supervising rendering-based studio projects.

The Data collection process employed semi-structured interviews and non-participant observation. Semi-structured interviews served as the primary instrument for collecting qualitative data. An interview guide was developed from the research objectives to ensure consistency while allowing participants sufficient flexibility to elaborate on their experiences. The interviews explored participants' experiences regarding:

- rendering duration;
- hardware limitations;
- workflow interruptions;
- software performance;
- project completion challenges;
- perceptions regarding render farm implementation.

Again, observation complemented the interview data by enabling the researcher to examine rendering activities within the studio environment. The observations focused on:

- computer specifications;
- rendering duration;
- workflow interruptions;
- hardware performance;
- overheating;
- rendering failures;
- students' interactions with available computing resources.

Institutional approval was obtained before data collection commenced. Participants were informed about the purpose of the study, and informed consent was obtained before participation. Individual interviews were conducted using the semi-structured interview guide and audio-recorded with participants' permission. The recordings were subsequently transcribed verbatim using Microsoft Word. Observational data were collected during practical studio sessions where students rendered their animation projects. Notes concerning rendering performance, hardware behaviour, workflow interruptions, and rendering duration were documented to supplement the interview findings. The combination of interviews and observations provided methodological triangulation, thereby strengthening the credibility of the findings.

The study employed thematic analysis following the six-step framework proposed by Braun and Clarke (2006). Interview transcripts were repeatedly reviewed to identify recurring patterns relating to rendering challenges, workflow limitations, hardware constraints, and participants' recommendations. Themes emerging from the analysis were interpreted alongside relevant literature to answer the research questions and inform the proposed render farm implementation framework. To ensure methodological rigour, the study adopted the trustworthiness framework proposed by Lincoln and Guba (1985). Credibility was enhanced through methodological triangulation by combining interview and observational data. Dependability was ensured by documenting every stage of the research process, including participant selection, interview procedures, coding, and theme development. Confirmability was strengthened by maintaining an audit trail comprising interview recordings, verbatim transcripts, field notes, coding records, and analytical decisions.

Transferability was enhanced through detailed descriptions of the study context, participants, and research procedures, enabling readers to assess the applicability of the findings to similar educational settings. The researcher is a lecturer within the Department of Graphic Design at the University of Education, Winneba and is therefore familiar with the educational context and the rendering challenges experienced by students. While this familiarity facilitated access to participants and provided contextual understanding, conscious efforts were made to minimise researcher bias throughout the study. To enhance objectivity, interview questions were standardised and aligned with the research objectives. Participants were encouraged to express their views freely without influence or interruption. Interview responses were transcribed verbatim, and thematic interpretations were grounded in participants' accounts rather than the researcher's prior assumptions. Observation notes were used to corroborate interview findings, thereby strengthening the credibility and confirmability of the study.

4.0 Discussion

The findings of this study have important implications for animation education, institutional infrastructure planning, and digital creative practice within higher education. From an educational perspective, the study demonstrates that the quality of students' practical learning experiences is influenced not only by curriculum content and instructional delivery (Putra et al., 2024) but also by the computational resources available for production activities. As Jia et al. (2026) have indicated, rendering constitutes a critical stage within the 3D animation workflow, and prolonged rendering durations reduce opportunities for experimentation, iterative refinement, and critical evaluation of visual outputs. Consequently, limitations in rendering infrastructure can inadvertently constrain students' creative development and technical competence. Institutionally, the findings suggest that investments in specialised computing infrastructure should be regarded as integral components of animation education rather than optional technological enhancements. This confirms the assertion by Nazari et al. (2024) that a centralised render farm has the potential to improve resource utilisation, promote equitable access to computational power, and support increasing student enrolment without proportionally increasing individual hardware requirements.

The study also contributes to the broader discourse on digital infrastructure within higher education institutions in developing countries. While considerable attention has been devoted to software acquisition and curriculum development, comparatively limited emphasis has been placed on rendering infrastructure despite its central role in contemporary computer graphics production power (Zhang, 2024). The proposed render farm framework therefore provides a practical model that may guide similar institutions seeking to strengthen studio-based digital production environments. The Department of Graphic Design should prioritise the gradual establishment of a centralised render farm to support animation production courses. Initial implementation may begin with a modest number of high-performance rendering nodes capable of handling final-year projects before subsequent expansion to accommodate the broader student population. The department should also establish standardised rendering workflows that promote efficient resource allocation, centralised asset management, and equitable access to rendering services.

Furthermore, the University management should recognise rendering infrastructure as an essential educational resource comparable to laboratories used within science and engineering disciplines. Budgetary allocations for animation education should therefore include dedicated funding for rendering hardware, storage infrastructure, networking equipment, uninterrupted power supply systems, and routine maintenance. Institutional partnerships with technology companies and digital media organisations may also provide opportunities for infrastructure development through collaborative projects, equipment donations, or research grants (Logue & Grimes, 2022). Students should be encouraged to adopt efficient rendering practices during project development. Scene optimisation, texture management, lighting efficiency, and appropriate sampling strategies should become integral components of animation instruction to reduce unnecessary computational overhead. Students should likewise receive training in distributed rendering workflows commonly employed within professional animation studios to improve industry preparedness.

Again, educational policymakers should recognise digital production infrastructure as a strategic investment in Ghana's creative economy. Supporting computational infrastructure within animation programmes will contribute to workforce development, digital entrepreneurship, visual communication, game development, architectural visualisation, film production, and other sectors increasingly dependent upon computer-generated imagery.

Indeed, future studies can evaluate the effectiveness of an operational render farm following implementation within a university environment. Such investigations may compare rendering duration, project quality, learning outcomes, and student satisfaction before and after implementation. In addition, comparative studies involving multiple universities offering animation programmes would further enhance understanding of rendering infrastructure challenges across different institutional contexts. Researchers may also investigate the educational feasibility of cloud-based rendering services as alternatives to locally installed render farms, particularly for institutions with limited financial resources.

Additional studies examining the integration of artificial intelligence, GPU-accelerated rendering, and hybrid cloud rendering workflows within animation education would further contribute to the modernisation of digital production curricula. Finally, economic feasibility studies comparing locally hosted render farms with commercial cloud rendering services would provide valuable guidance for institutional decision-making regarding long-term infrastructure investment.

5.0 Conclusion

This study investigated the rendering challenges experienced by Animation and Multimedia students within the Department of Graphic Design at the University of Education, Winneba, and examined the potential of a centralised render farm as a sustainable solution for improving animation production workflows. The findings demonstrate that rendering constitutes one of the most significant technical constraints encountered during studio-based animation production. Limited computational resources were found to increase rendering duration, reduce opportunities for iterative design, constrain creative experimentation, and influence the overall quality of students' visual outputs. These challenges extended beyond technical inconvenience to affect learning experiences, project completion, assessment outcomes, and students' preparedness for professional practice.

Participants consistently identified the establishment of a departmental render farm as a practical strategy for enhancing rendering efficiency, promoting equitable access to computational resources, and improving the quality of studio instruction. Guided by these findings, the study proposed a scalable render farm implementation framework designed to support contemporary animation education while remaining adaptable to the financial realities of higher education institutions. Beyond addressing an institutional challenge, this study contributes to the broader discourse on digital infrastructure within creative arts education. It argues that effective animation education depends not only on curriculum design, software availability, and instructional expertise but also on the computational capacity required to support modern rendering workflows. As rendering technologies continue to evolve and visual production standards become increasingly sophisticated, investment in centralised rendering infrastructure will become progressively more essential for institutions seeking to produce graduates capable of competing within the global digital creative industry.

Ultimately, the study provides both empirical evidence and a practical implementation framework that may inform future infrastructure planning, institutional policy, and animation education research within Ghana and other developing contexts. The Sustainable Educational Render Farm Model (SERFM) provides a scalable conceptual framework that integrates centralised rendering infrastructure, distributed computing, resource sharing, and pedagogical objectives to improve animation education within resource-constrained higher education institutions as can be seen in figure 5.

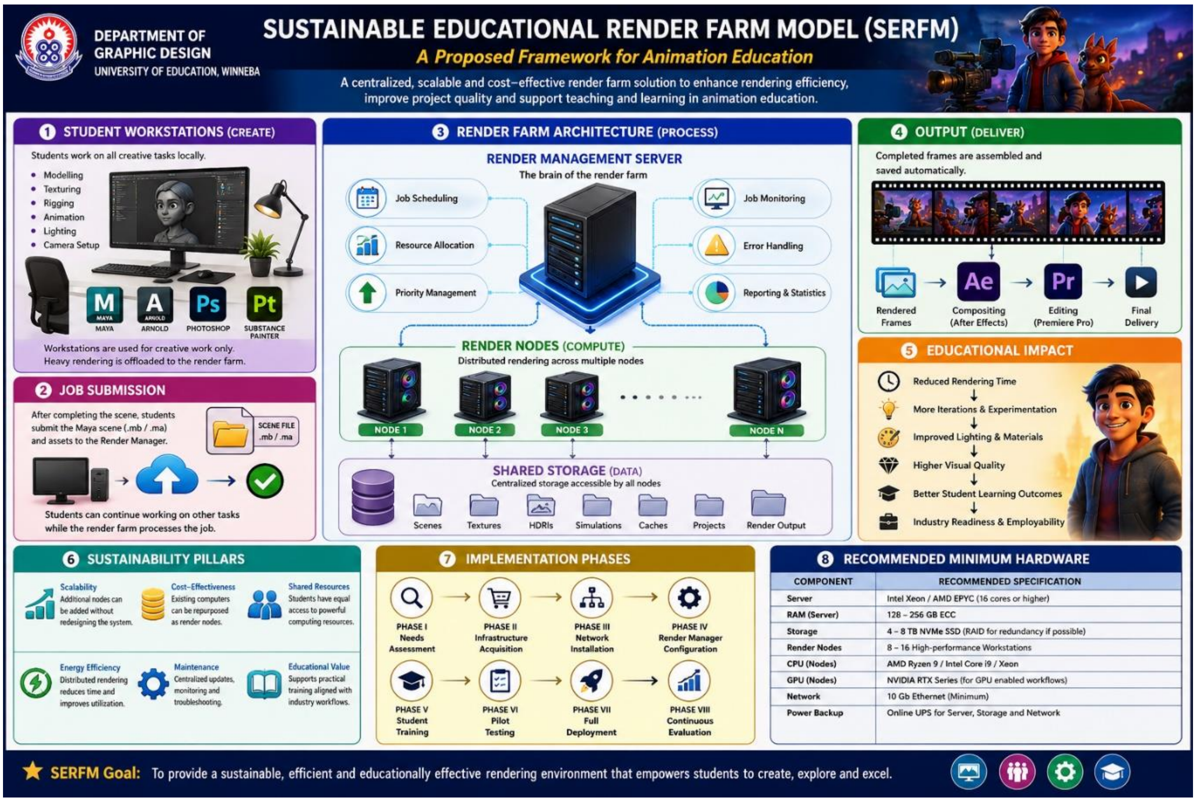

Figure 5: Proposed render farm model designed by researcher

The paper concludes that a render farm is essential for enhancing animation and motion graphics education at UEW and improving student performance.

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