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Application of Virtual Reality in the Companies of the Future

Visualizing the World of Manufacturing through Virtual Reality

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Abstract

Design and manufacturing companies of the future will encounter unique challenges from the advent of wider availability of technology, information, and ever-growing competition from the development of countries worldwide. The ability of a company to compete in these markets falls heavily upon the abilities possessed by its employees and the technology utilized during the design and manufacturing process. The demand for newer products has seen the timeline for product development shorten drastically, resulting in the need to implement technology to meet these desired deadlines. Application of virtual reality into the design and manufacturing process would afford the employee to effectively invent and innovate products and provide further visualization methods for both the employee and consumer. Through the increased use of virtual reality, employees better understand consumers' desires. This essay details the technology required for smooth implementation of virtual reality throughout the design and manufacturing process. Further discussion topics throughout this essay include the current shortcomings of virtual reality technology and the required partnerships and research to improve further and ensure the effectiveness of virtual reality throughout the company.

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1. Introduction

We are living in the Information Age. Using computers and other forms of media, limitless amounts of knowledge rest at the edge of an individual's fingertips continuously throughout the day. This expanse of knowledge worldwide is shown in the fact that during fourteen years, global reach of mobile phones rose from a mere 12% to 96% [1]. This trend is similar for other devices; over thirteen years, tablets increased from 3% to 53% [2]. This adoption of digital technology has not been exclusive to personal use but has also seen widespread adoption in industrial settings as well. Initiatives have been started worldwide by many nations and multinational organizations to maintain competitive advantage and support growth. These initiatives have targeted a particular set of technologies that aim to shift industry from labor-intensive to information-intensive, allowing flexible design and manufacturing processes to be implemented. This technology is not exclusive, with many companies developing partnerships or starting internal development of these technologies. This introduces a level playing field for all companies in the global market. To become a leading design and manufacturing company, it becomes necessary for a company to maintain a technological edge ahead of its competitors [3].

In the rapidly evolving era of technology, keeping up with the latest advancements can be overwhelming. With countless options and capabilities available, adopting every new technology within a company is unrealistic. Hence, it becomes crucial to determine the most efficient technologies to prioritize time and resources on. One cost effective resource that is being implemented is virtual reality (VR). VR refers to a computer-generated simulation of an environment that immerses users in a three-dimensional, interactive experience. Through specialized hardware, such as headsets and gloves, users can perceive and interact with a virtual environment that simulates the real world or an imagined one. Innovations in VR technology have seen the adoption of the technology in ways that seem inspired by science fiction rather than the traditional design and manufacturing methods. The image below displays just one of many possible uses of virtual reality during the design process, specifically regarding vehicles.

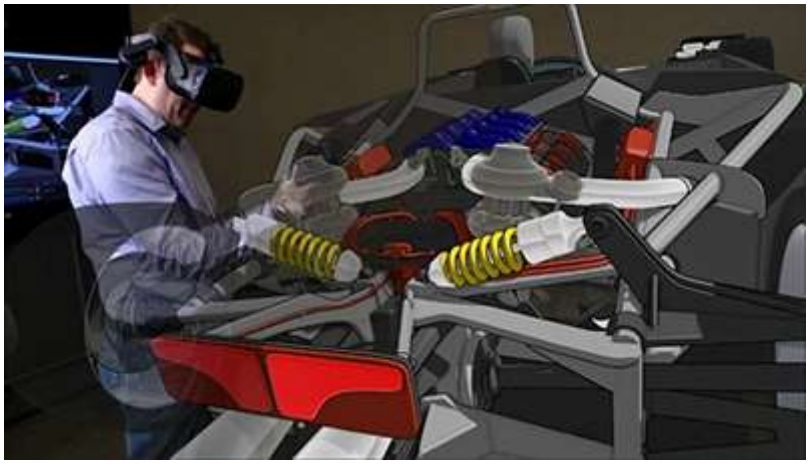

Figure 1: System Visualization in VR [4]

2. Background

The ever-growing expanse of the world's population continues to gain access to modern amenities and countries continue to modernize, transitioning into later-stage demographic countries. To meet the demands of these growing markets, there is a need for continuous development, which requires the design and manufacturing industry to be incredibly flexible and dynamic [5]. However, the goals and definitions of these companies remain relatively the same[6]. The key characteristics for company success in the Information Era are shown in Figure 2 below.

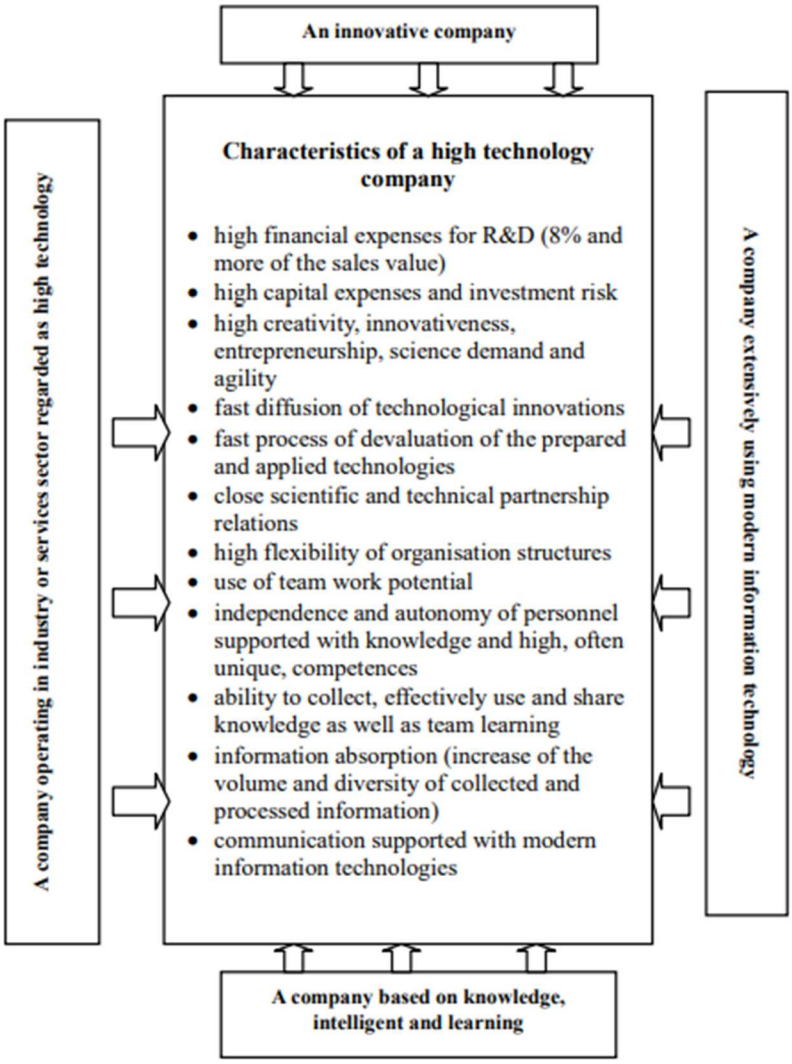

Figure 2:Characteristics of a Competitive Company [6]

Presently, design and manufacturing methods heavily rely on human involvement. The company's engineers follow a systematic design process, utilizing sketches, computer software, and prototypes to transform concepts into tangible products. These products are then mass-produced and introduced into the consumer market to meet customers' evolving demands. To maintain a competitive edge within the market, companies seek methods of improving product development efficiency and effectiveness between the various stages and groups involved throughout the design

and manufacturing process [7]. The technology industry and researchers are persistent in developing new ways to implement virtual reality (VR) into the design and manufacturing process. Through early utilization of VR, many benefits have been found that result in a better final product and faster product development cycle[8].

3. Virtual Reality in Design

The design process holds utmost significance in the development of successful market products. During this phase, requirements are identified, calculations are conducted to ensure the product adheres to constraints, and the concept is transformed into a tangible reality. With demands for products requiring shorter development cycles, time management has been crucial at every step of product development – from brainstorming to product release. Despite VR being first developed in the 1970s, the technology has only, in the past decade, reached the point of wide availability [9]. This has led to the development of VR into a technology that provides enhanced visuals at affordable prices [10]. With such technology, designers could visualize high-fidelity designs consistently throughout the design process, determining the best decisions with the need for lengthy creation of physical prototypes.

VR has allowed enhanced integration of key personnel further into the design process – the customer. VR affords the ability to 'see' the design through the various stages of the process. Beyond visualization of various prototypes for design decisions, these prototypes can also be shown to consumers in a way that has never been presented before. Alongside this visualization, models can be further developed to determine how consumers would utilize the product in everyday life [11]. Using this type of product testing and feedback gathering, information could be attained relating to various conditions of products during use and interaction of the product with its surrounding environment [10]. Through this approach to the design process, production of prototypes would be greatly increased, prototype waste would decrease, and overall understanding of the prototypes would lead to a better final product.

Difficulties in Implementing Virtual Reality in Design

Due to the rapid proliferation of VR into mainstream use, a lag has been created between the hardware and the software utilized. Firstly, the software currently available to VR systems leaves much to be developed, as there are very few options available for companies to develop and design products. Furthermore, with current software available, all desired features for the company may not be present in a single software, resulting in further costs for multiple software licenses or reduced prototype fidelity. A further consideration is the process of implementing prototypes into a VR environment. Currently this process requires multiple different software, with the 3D model, rendering, and VR engine all being separate software. This is shown Figure 3. This greatly reduces the potential efficiency and will require more training for designers.

Figure 3: VR Modeling Process [12]

As shown above, the three components are locked in a linear process, requiring three separate software. Each is responsible for different aspects of a VR model; first, there is the model itself, then the model is rendered, and then the engine is implemented to display it in VR. This software may not offer previews of desired characteristics in the model, which may require the process to be followed through, only to find erroneous errors, requiring a restart from the beginning.

4. Virtual Reality in Manufacturing

Virtual Reality offers a great potential that has yet to be fully unleashed in the manufacturing stage of a product's lifecycle. Early adopters of innovative technologies, such as VR, have seen great success in the use of technology. Specifically, small, and medium enterprises (SMEs) have seen an estimated growth in efficiency of 26% on average. In terms of monetary value, these technologies have been projected to create an additional $3.7 trillion by 2025 [13]. These improvements are primarily linked to facilitating key factors in the design process, such as promoting critical, practical, and effective decision-making [14].

As the name suggests, information is one of, if not the most, paramount components to success in present manufacturing. An enormous amount of information is available to a designer early in the design process. Due to the vagueness present early in the design process, the relevant data becomes apparent as the design process continues. However, decisions made early in the design process require a great deal of resources, money, and (most importantly) time to be invested. Relevant data that is discovered later can result in unforeseen consequences from the initial design phases, which result in unforeseen costs. VR offers a method to gather information about a decision using modeling and simulations, allowing for more informed decisions far before procuring exorbitant expense [15].

Furthermore, the incorporation of VR into manufacturing extends beyond mere decision-making assistance. It also fosters collaboration among geographically dispersed teams and stakeholders. Through the creation of immersive virtual environments, VR enables synchronous collaboration, enabling designers, engineers, and stakeholders from diverse locations to engage in joint design reviews. This expedites decision-making and enriches communication, resulting in streamlined workflows and ultimately enhanced product quality.

Difficulties in Implementing Virtual Reality in Manufacturing

Despite the recent adoption of VR in the manufacturing space, there have been several concerns relating to the implementation of the technology into this area. VR hardware is affordable,

however, as most hardware is designed for consumer use, many considerations have not been accounted for in industry use. Main areas of concern include that the VR hardware isn't designed for use throughout the traditional 8-hour workday. Also, these headsets do not meet the safety standards set by OSHA for use in the manufacturing setting, notably following safety glasses regulations. Furthermore, implementing VR into manufacturing spaces presents ergonomic challenges, with VR often requiring large spaces to work effectively. Some compiled challenges are presented in the following figure below [16].

			Beckhoff Automation	Herman Miller	Fluiconnecto
Challenges	Technology	User interface	Sufficient visibility of content Sufficient field of view	Sufficient visibility of content Sufficient field of view	Sufficient visibility of content Sufficient field of view
		Weight	Too heavy for 8h	Too heavy for 8h	Too heavy for 8h
		Tracking technology	Needs improvement for field service	Sufficient	Sufficient
		H&S	No concerns	Not all HDMs fulfil safety glasses regulation Distraction by AR was problematic on shopfloor	Not all HDMs fulfil safety glasses regulation
	Organisation	User acceptance	Customisable instructions necessary	More experienced operators are more sceptical	AR is not well known - fear of change and unknown
		Organisational structure	Lack of integration possibilities into enterprise systems (ERP, MRP, etc.)	No concerns	No concerns
		Shop floor processes	No concerns	Shop floor needs to be adapted (lightning conditions, anchor points, assembly steps, moving parts)	Shop floor needs to be adapted (space around operator to use gestures) No need for adaption if only used for training
		Cost	Content authoring is costly Hardware prices are low enough	Content authoring is costly Hardware prices are low enough	Hardware prices are low enough
	Environment		–	–	–

Figure 4: Challenges of VR Implementation [16]

VR has documented adverse side effects with persistent use as well. Most notably users experience "cybersickness." This causes the user to experience nausea, dizziness, and lightheadedness symptoms. Though the exact cause is unknown, this hinders user accessibility and development. Further, it has been documented that VR can cause eye strain with prolonged use, with further chronic issues yet to be discovered or documented [10].

5. Proposed Company Profile

To successfully integrate virtual reality (VR) technology, the company must allocate substantial resources towards its development. Beyond integrating VR into design and manufacturing processes, ensuring that any platforms introduced align closely with the company's specific requirements and further enhance existing methodologies is crucial. Moreover, these technologies must be implemented in a way that is conducive to widespread use and adoption by employees across various departments. Achieving this goal will require establishing strategic partnerships and identifying critical areas for research and development. By investing in these initiatives, the company can position itself at the forefront of innovation within its industry while optimizing operational efficiency and productivity.

Research Challenges

As virtual reality technologies continue to advance, numerous research challenges arise. This becomes particularly crucial when integrating virtual reality technologies that ensure the safety of human workers, streamlined prototype processes, and enhanced user experience. The following research challenges are key focuses the company would need for successful integration into a manufacturing process.

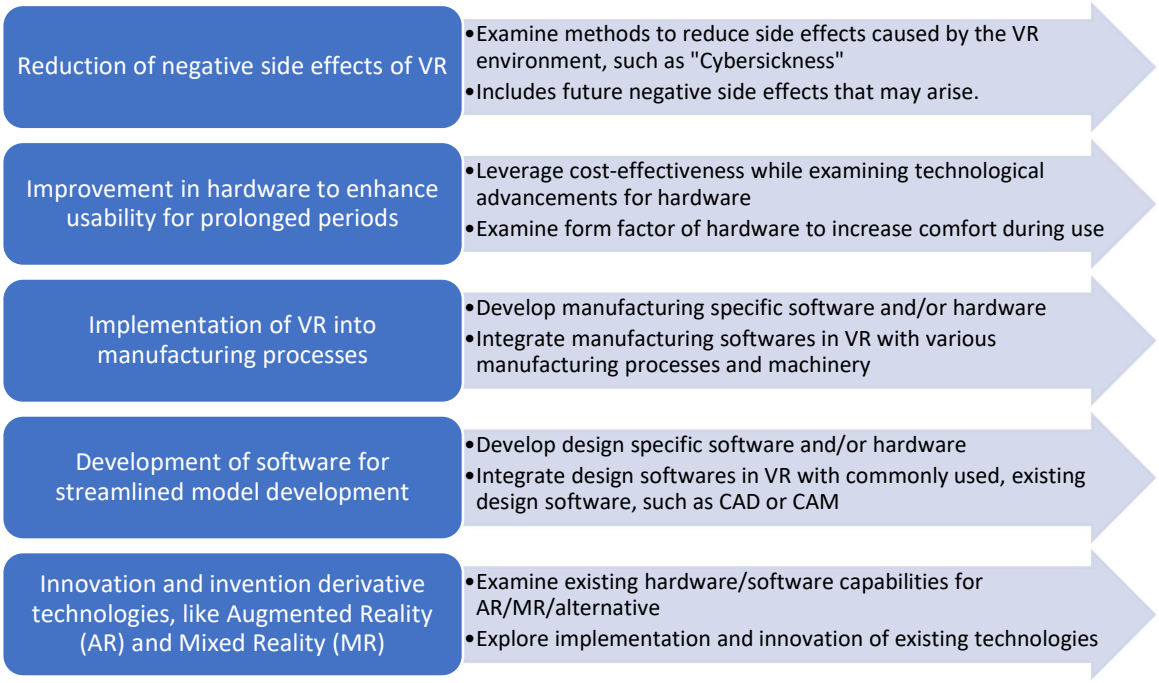

Figure 5: Research Challenges to be Addressed

The primary challenge revolves around mitigating the adverse effects of VR usage, such as cybersickness and eye strain. Significant progress has been made in addressing these issues by enhancing the screen resolution and refresh rate of VR headsets, which has proven effective in reducing cybersickness occurrences. However, widespread adoption of these upgraded hardware specifications has been hindered by increased costs, additional external requirements, and diminished battery efficiency. To enhance accessibility to improved VR headsets, research efforts need to concentrate on enhancing the operational capabilities and power efficiency of compact processing units. This would minimize the space requirements of current VR devices, facilitating their widespread deployment in conventional business settings.

Furthermore, efforts to refine the ergonomics of VR systems are essential. The industry has introduced various methods of wearing VR headsets, from basic display boxes for phones to goggle setups like the Apple Vision Pro and head harnesses such as those used in the HTC Vive. Each of these approaches offers unique advantages, and ongoing research aims to optimize user comfort for extended periods of use.

The following two research challenges, while similar, present unique requirements. Integrating VR into manufacturing necessitates ongoing refinement of manufacturing-specific software, encompassing programs tailored to individual companies or domains. For instance, if a corporation utilizes particular machinery or requires specialized training, corresponding software should be

developed to replicate current or future conditions. This would allow employees to conduct training to develop the knowledge and skills required without the added risks or the time, and therefore money, taken away when a machine is used for training instead of manufacturing. Moreover, there's a need for software applications finely tuned to meet the specific demands of the manufacturing process. Although VR has found some applications in computer-aided design (CAD), further optimization would provide designers with alternative perspectives on designs in form and function. VR has also seen the development of accessory hardware that allows the stimulus of other senses, such as touch using haptic feedback. This additional stimulus would allow designers to "feel" a product and how it functions before producing a physical prototype. Furthermore, VR can serve as a platform for customer interaction, facilitating product engagement and feedback gathering. By leveraging VR as a display medium, businesses can enhance customer decision-making processes by providing immersive experiences and expanded information channels, such as visualizing customizable features on vehicles.

In addition to exploring virtual reality (VR), it is imperative to delve into derivative technologies such as augmented reality (AR) and mixed reality (MR). Unlike VR, AR and MR allow users to interact with the real and virtual worlds simultaneously. This unique capability opens doors to enhanced productivity for workers, enabling them to execute tasks in the physical realm while accessing essential information through AR/MR overlays. For instance, workers can seamlessly access instructions and specifications for assembly processes, enhancing efficiency and accuracy on the factory floor. Moreover, AR and MR technologies hold immense promise in the planning and constructing of facilities. By overlaying virtual blueprints onto physical environments, workers can visualize and assess critical components of structures or processes in real time, facilitating better decision-making and precision during construction phases. As such, continued research and development in AR and MR are essential for unlocking their full potential in the manufacturing and construction industries.

Necessary Partnerships

Establishing and nurturing partnerships with VR design and manufacturing companies is imperative for successfully adopting this transformative technology. This need is particularly pronounced when striving to meet the specific requirements and preferences of the company. For instance, there may be a need for hardware or software features that are currently limited or non-existent in the market. Collaborating with industry partners can facilitate the development of these technologies to meet the company's bespoke needs. Additionally, forging alliances with academic institutions specializing in virtual reality research can yield valuable insights and innovations, as demonstrated in the preceding section. Table 1 provides illustrative examples of the essential partnerships the company should prioritize in its pursuit of technological advancement and competitiveness.

Table 1: Partner Organizations [17], [18]

Industrial Partnerships	Academia Partnerships
Facebook Reality Lab	Massachusetts Institute of Technology
Magic Leap	Stanford University
Microsoft	University of South Carolina
Google	University of Washington
Unity Technologies	New York University
NVIDIA	Georgia Institute of Technology
Apple	University of California – Berkeley
Qualcomm	Rochester Institute of Technology
Vuzix	Texas A&M University at College Station
PTC	University of North Carolina at Chapel Hill

The industrial partnerships primarily consist of companies commonly known as "Big Tech," a unsurprising designation given their extensive development branches and capacity to create hardware and software solutions to support their technologies. Noteworthy examples include Facebook, Microsoft, and Google, all of whom play pivotal roles in shaping the VR landscape. It is also crucial to forge partnerships with specialized software companies such as Unity, Vuzix, and PTC, as they will play a vital role in developing bespoke software solutions tailored to the company's needs. In addition to collaborating with these industry-leading experts, securing reliable sources for the company's hardware is paramount, with NVIDIA and Qualcomm emerging as key players given their dominance in the global microchip supply chain.

Academic institutions play a dual role for companies, serving as both hubs for research and avenues for training. The universities listed boast comprehensive degree programs and robust research initiatives focused on VR and associated technologies, positioning them as invaluable resources for companies developing optimal VR systems. Moreover, many of these academic institutions offer certification programs in VR technologies, such as MITs “MIT xPro” [18]. Leveraging these programs strategically, companies can provide employees with specialized training in VR utilization and troubleshooting, enhancing their proficiency and effectiveness in leveraging this transformative technology.

6. Conclusion

The successful integration of VR technology into design and manufacturing processes will be indispensable for high-tech companies in 2040. By leveraging VR, companies can streamline design-prototype cycles, leading to greater efficiency and effectiveness in product development. VR technology offers unparalleled capabilities in displaying models, enabling rapid experimentation and iteration that would traditionally require extensive time investments. Moreover, VR facilitates unprecedented collaboration with customers, allowing for immersive and interactive experiences that enhance product customization and user engagement. In manufacturing, VR holds immense potential for revolutionizing processes through enhanced visualization and comprehension of manufacturing operations. However, alongside these benefits, it is essential to address and resolve potential drawbacks associated with VR technology to realize its advantages fully. Looking ahead, the widespread adoption of VR has the potential to profoundly

alter daily life, offering immersive experiences in various domains beyond design and manufacturing, including entertainment, education, healthcare, and beyond.

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[19] Grammarly and GhatGPT

7. Appendix

This work submitted is built off the foundation of a previous design essay produced. With the recent innovations to AI, and the spirit of this design essay contest, AI was attempted to be used to enhance the essay. The author attempted to give the essay to various AI, Gemini, Copilot, and ChatGPT, however found that without access to premium versions of these AI, that was not possible. When copying and pasting the text, the issue of character limits arose for the same reason. Breaking the essay up into chunks resulted in the AI often disregarding sections of the paper, and based off previous comments, would add sections already present in the paper. ChatGPT proved most useful when presented with queries that narrowed down to general topic discussions focused on feedback instead of large blocks of text. These queries and responses included:

- How best to define Virtual Reality? "Virtual Reality (VR) can be defined as a computer-generated environment that simulates physical presence in real or imagined worlds, allowing users to interact with and manipulate objects and entities within that environment."

-What are issues with VR in the Design Process? "Issues with VR in the design process can include:1. Hardware Limitations: High-quality VR hardware can be expensive and may require significant processing power, limiting accessibility to some designers. 2. Cybersickness: Extended use of VR can lead to cybersickness or discomfort for some users, which can affect their productivity and experience. 3. Learning Curve: Designers may require time to adapt to using VR tools effectively, potentially slowing down the design process initially. 4. Limited Integration: VR tools may not seamlessly integrate with existing design software or workflows, leading to inefficiencies in data transfer and compatibility issues. 5. Quality of Visualization: The quality of visualizations in VR environments may vary, impacting the accuracy and realism of designs. 6. Collaboration Challenges: Collaborating on designs in VR may pose challenges, especially for dispersed teams, due to limitations in communication and interaction within virtual environments. 7. Data Security: Storing and sharing design data in VR environments may raise concerns about data security and intellectual property protection. Addressing these issues requires continuous improvement in VR technology, user training, integration with existing design processes, and consideration of collaboration and security concerns."

-What is XR in VR? "Extended reality (XR) is an umbrella term that encompasses virtual reality (VR), augmented reality (AR), and mixed reality (MR). XR refers to immersive technologies that blend the physical and digital worlds, providing users with interactive experiences that can range from fully virtual environments to real-world environments enhanced with digital elements."

These queries though basic allowed the author to grasp a deeper understanding of the topic and better present findings in the research. This greatly improved sections of the paper previously heavily criticized, notably section 4.Virtual Reality in Manufacturing and 5.Proposed Company Profile, which lacked detailed descriptions of the topics discussed and was left in layman's terms. Grammarly proved vital to the restructuring of the paper, greatly improving the readability and word choice throughout when the goals are set to academic and professional settings.