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How Does Computer Vision Reshape Higher Education? A Comprehensive Review

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Abstract— Computer vision technologies are transforming higher education by enhancing learning experiences, streamlining administrative processes, and fostering inclusivity. This comprehensive review examines recent literature, highlighting key applications such as immersive learning, automated grading, and campus management. The review also addresses the ethical challenges and infrastructural barriers, particularly in Moroccan higher education, where digital transformation is still evolving. The findings suggest that while computer vision holds great promise, careful consideration is needed to ensure equitable and ethical implementation. Future directions include addressing these challenges to fully realize the potential of computer vision in creating an adaptive and inclusive educational ecosystem.

Keywords— Computer vision; educational innovation; higher education; learning outcomes; pedagogical transformation.

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1. Introduction

The integration of computer vision technologies in higher education fundamentally alters how learning is conceived, delivered, and experienced. These technologies offer new opportunities to enhance educational practices, from enriching learning materials with immersive visuals to automating grading and personalizing learning experiences. This review examines the current applications of computer vision in key areas such as learning enhancement, teaching support, and campus management. It also addresses the ethical challenges and infrastructural barriers, particularly within the Moroccan higher education context. The paper is structured to discuss these applications, provide specific case studies, explore emerging trends, and consider the implications for future educational practices.

A. Inclusion and Exclusion Methodology

The literature review focused on studies published from 2020 onwards in indexed journals and conferences to ensure the inclusion of the latest research. The primary search filter used was “computer vision in higher education,” with specific keywords such as "virtual reality," "augmented reality," "object classification," "object detection," and "reinforcement learning." Papers were included if their title, abstract, or keywords explicitly referenced these terms within the context of higher education.

Studies that did not meet these criteria or lacked direct relevance were excluded “Fig. 1”. This streamlined approach ensured a curated selection of current and pertinent literature, highlighting the evolving role of computer vision in educational settings.

B. Introduction to Computer Vision in Higher Education

The use of computer-based educational technologies in higher education is a growing trend, with students showing a preference for these tools (Makaradze et al., 2021). These technologies, including computer vision, are being increasingly applied in higher education, particularly engineering education, to improve student performance and teaching-learning processes (Rawat & Sood, 2021). Artificial intelligence, a key component of computer vision, is also being utilized in higher education, with machine learning, augmented reality, and learning management systems being identified as study hotspots (Chin & Wang, 2021). Augmented reality, a technology closely related to computer vision, is used to enhance the effectiveness of mobile-oriented learning environments, stimulating the educational process and motivating students to self-study (GUREVYCH et al., 2021).

These findings underscore the importance of computer vision technologies in higher education, as they can potentially improve the quality of education and enhance the learning experience.

Part II provides a comprehensive exploration of the various applications of computer vision in higher education, including Learning Enhancement, Teaching Support, Campus Management, Research and Development, Accessibility and Inclusivity, Collaboration and Communication, and Skill Development. Part III details specific use cases, followed by an analysis of the trends in the application of computer vision in higher education in Part IV. The Moroccan context is specifically examined in Part V. Lastly, the conclusion presents a conceptual mapping of the review's key components.

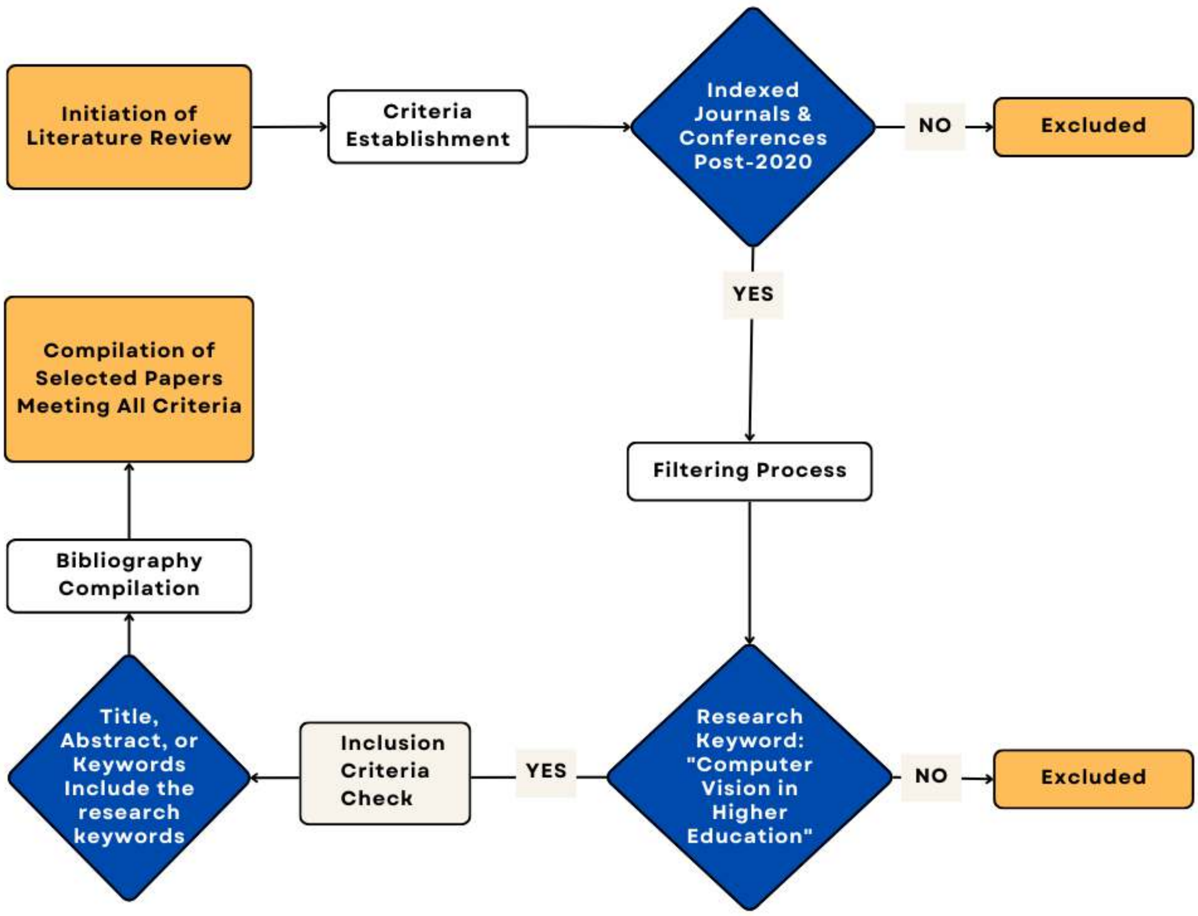

Fig. 1.: Selection Process for Computer Vision in Higher Education Papers

2. Current Applications Of Computer Vision In Higher Education

A. How Computer Vision Works

Computer vision operates through several stages, from image acquisition and preprocessing to feature extraction and classification. The accompanying flowchart illustrates how these stages are integrated into a real-time system. Starting with image acquisition, the system preprocesses data to filter noise and emphasize regions of interest. Next, the system extracts features, identifying key patterns before feeding them into machine learning models, which classify objects or detect anomalies. The feedback loop enables continuous learning, improving accuracy with each iteration.

As demonstrated in the work by (Z. Li et al., 2024), convolutional neural networks (CNNs) play a pivotal role in anomaly detection, processing large volumes of image data efficiently. Their study highlights how feedback loops, as depicted in the flowchart "Fig. 2", enable real-time adjustments, ensuring better performance in tasks like object detection and classification. Integrating such systems into educational platforms, as outlined, can significantly enhance automation and accuracy in computer-based assessments.

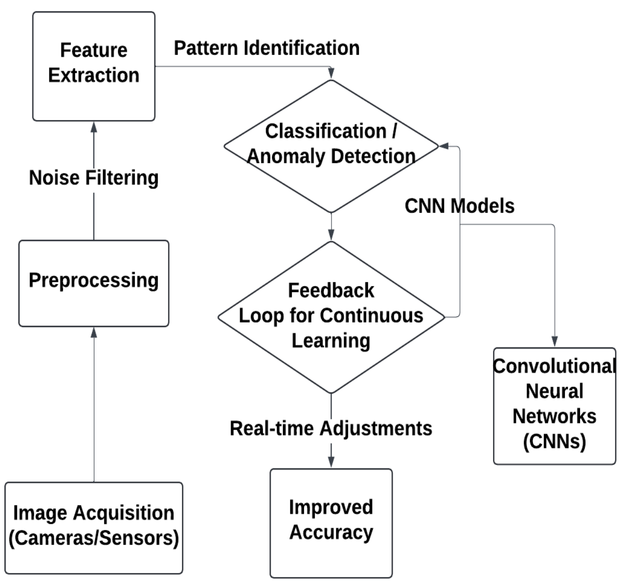

Fig. 2 : A Detailed Flowchart of the Computer Vision Process

B. Learning Enhancement

1) Visual Aids and Illustrations

Recent research has explored the potential of incorporating computer vision into educational materials to enhance learning experiences. (Jiang, 2021) developed an interactive teaching platform using virtual reality (VR) technology, which can be particularly useful for vocational education. (Mateen & Kan, 2021) proposed the use of VR technology to provide distance learning in medical education, particularly for anatomy and clinical scenarios. (Wróblewska et al., 2022) explored the automatic detection of qualitative features of lecturing using computer vision, which has the potential to improve the assessment of academic lectures. These studies collectively highlight the potential of computer vision in enhancing traditional educational materials with interactive visuals, diagrams, and simulations.

2) Augmented Reality (AR) and Virtual Reality (VR)

A range of studies have explored the use of immersive technologies in education, particularly in the fields of anatomy, architecture, and historical reconstruction. (Hendricks, 2022) highlighted the potential of augmented reality (AR) as a blended learning tool in architectural education, particularly in technical and practical components. (Back et al., 2020) demonstrated the benefits of immersive collaborative learning in CAVE-based virtual reality, with significantly higher learning gains compared to conventional textbooks, particularly for low spatial ability learners. (Fathallah et al., 2022) emphasized the potential of virtual reality (VR) applications in architecture education, particularly in design studios, as a means of improving the educational process. Moreover, Extended Reality (XR) technology, encompassing AR, VR, and Mixed Reality, is increasingly recognized for its role in education, especially in enhancing practical skills and offering immersive, real-time experiences in STEM education (Sembey et al., 2024). These studies collectively underscore the potential of immersive technologies in enhancing learning experiences in various educational contexts.

C. Teaching Support

1) Automated Grading and Assessment

Recent research has made significant strides in the development of computer-aided assessment systems, particularly in the field of education. (Bernius et al., 2022) introduced Athene, a system that uses topic modeling and language embedding to grade textual exercises at scale, significantly reducing the manual workload for instructors. Similarly, (Kulmethe & Hajare, 2020) presented ∞Exam, a software system that uses image processing to correct multiple-choice questions, further streamlining the grading process. AI-driven systems, such as intelligent tutoring systems, further enhance this by providing real-time feedback, leveraging machine learning to adapt to individual student performance and adjust assessments dynamically (Sembey et al., 2024). Additionally, sentiment analysis and data mining techniques play an important role in evaluating student feedback and emotions to further refine the educational experience. By analyzing these emotions, AI systems can adjust teaching strategies in real time, promoting better student engagement (Bhoi & Thakkar, 2022). However, (González-Calatayud et al., 2021) highlighted the need for further research and teacher training to fully understand the potential of these systems in educational assessment.

2) Personalized Learning

A review of personalized learning technologies and applications in higher education from 2010 to 2021 found that self-adaptive learning and relevant learning information can improve study efficiency (Ambele et al., 2022). However, the responsible application of personalized and adaptive learning is crucial, considering the diverse learning styles and progress of individual students (Costa et al., 2021). To effectively implement personalized education, a dynamic framework that considers the changing nature of learners and their interactions with the instructional process is proposed (Tetzlaff et al., 2021). This framework emphasizes the need for instructional design to adapt to specific learners at specific points in time.

D. Campus Management

1) Security and Surveillance

The use of computer vision for campus security and surveillance is a growing trend, particularly in the context of smart campuses. (Zaballos et al., 2020) and (Alexei et al., 2022) both emphasize the importance of integrating building information modeling tools and IoT-based wireless sensor networks to monitor environmental parameters and ensure the security of sensitive data. (Cavus et al., 2022) further explores the benefits and challenges of implementing IoT-based smart campuses, highlighting the potential for computer vision to enhance security and monitoring. (Mazutti et al., 2020) provides a practical example of this, demonstrating how a smart and learning campus can use air quality monitoring to promote sustainability education. These studies collectively underscore the potential of computer vision in enhancing campus security and surveillance.

2) Resource Management

The use of computer vision systems in resource management, such as optimizing facility usage and monitoring attendance, has been explored in various contexts. (Qasem et al., 2020) presents a model for the continuance use of cloud computing in higher education institutions, emphasizing the importance of resource retention. (Alokluk, 2020) examines the attitudes of students towards library facilities, suggesting that understanding user perceptions is crucial for effective resource management. (Saiful Bahri et al., 2019) proposes an integrated facility and assets management system using GIS, which could potentially be enhanced with computer vision technology for more efficient resource utilization.

E. Research and Development

1) Data Analysis and Visualization

The use of data analysis and visualization in scientific research is a growing trend, focusing on enhancing students' critical thinking skills (Byrd & Asunda, 2020). This is particularly evident in the field of computer graphics, where there is a significant increase in research output (Sajovic & Boh Podgornik, 2022). The development of software components for data analysis and visualization, such as those used in digital cloud platforms, is also a key area of focus (Perepelkin et al., 2020).

Innovation in Learning Tools. The use of computer vision in educational tools is a growing area of interest, with potential applications in virtual reality (Figueiredo et al., 2021), information and communication technologies (Bravo & Gámez, 2021), and game-based learning (Dyulicheva & Glazieva, 2022). (Figueiredo et al., 2021) and (Bravo

& Gámez, 2021) both highlight the potential for these technologies to enhance the teaching and learning process, while (Dyulicheva & Glazieva, 2022) provide practical examples of tools that can be used to create educational games with AI and immersive technologies.

F. Accessibility and Inclusivity

1) Assistive Technologies

A range of studies have highlighted the importance of assistive technologies, particularly computer vision, in supporting students with disabilities. (Kisanga & Kisanga, 2022) emphasize the role of these technologies in facilitating learning and participation, calling for increased funding and support. (Nascimento et al., 2022) and (Ndlovu, 2021) further explore the provision of assistive technologies in specific contexts, with (Nascimento et al., 2022) noting disparities in the availability of these technologies and (Ndlovu, 2021) highlighting the need for improvement and the use of Universal Design for Learning. These studies collectively underscore the potential of computer vision and other assistive technologies in enhancing the educational experiences of visually impaired and differently-abled learners.

G. Collaboration and Communication

1) Remote Learning Platforms

A range of studies have explored the use of various online collaborative tools in remote learning. (Gopinathan et al., 2022) highlight the benefits of using platforms such as social media, and collaboration tools like Google Classroom to enhance student engagement and collaboration. (Bangay et al., 2020) further extends this discussion by exploring the potential of repurposing social virtual reality platforms for distributed learning. These studies collectively underscore the importance of real-time collaboration and the use of innovative tools in virtual classrooms.

2) Language Translation and Recognition

Numerous studies have examined the application of translation and multilingual pedagogies in higher education. (Wildsmith-Cromarty et al., 2022) and (González-Davies, 2017) both highlight the importance of these approaches in supporting linguistic diversity and enhancing language learning. (Zappatore, 2022) further emphasizes the need for training in these areas, particularly in the context of evolving technology and the COVID-19 pandemic. These studies collectively underscore the potential of real-time translation and transcription in creating inclusive and effective multilingual learning environments.

H. Skill Development

1) Coding and AI Education

(Chung & Lou, 2021) and (Barakina et al., 2021) both emphasize the importance of introducing AI and machine learning concepts to students, with (Chung & Lou, 2021) specifically focusing on K-12 education and (Barakina et al., 2021) discussing the broader societal implications. (Allen et al., 2021) and (Ali & Maynard, 2021) further this discussion by highlighting the need for best practices in teaching AI and the potential applications of AI in higher education, respectively. These studies collectively underscore the significance of integrating computer vision concepts into coding and AI education to enhance students' understanding of these technologies and their real-world applications.

2) Hands-On Learning

Recent studies have highlighted the potential of hands-on learning in computer science, engineering, and robotics. (Pirker et al., 2021) found that virtual reality can enhance learning outcomes and student engagement in computer science, particularly in the context of sorting algorithms. (Betz et al., 2022) introduced the F1TENTH autonomous vehicle platform, which has been successful in teaching autonomous systems and enhancing students' understanding and motivation. (Chookaew et al., 2020) demonstrated the benefits of STEM robot-based learning activities in developing students' computational thinking, particularly in high school science and engineering education. (Cao et al., 2021) explored the use of an online collaborative programming platform in teaching Python to civil engineering students, which proved effective in enhancing their learning experience. These studies collectively underscore the value of hands-on learning and the potential of computer vision in enhancing student engagement and learning outcomes in these disciplines.

3. Specific Use Cases And Case Studies

Computer vision has been successfully implemented in various sectors within higher education. (Holliman, 2021) used machine + human mixed intelligence for visualization quality assessment, while (Buckley & Nerantzi, 2020) explored the use of visual representation in research and teaching. (Adha et al., 2020) identified hardware, procedures, software, databases, telecommunication networks, and brainwave as key factors for the successful implementation of computer-based management information systems in universities. (Khan & Khojah, 2022) highlighted the role of artificial intelligence and big data in the adaptive e-learning system, which can enhance the learning experience and minimize dropout rates. These studies demonstrate the potential of computer vision in improving assessment, teaching, and learning processes in higher education.

Recent research further highlights the growing importance of computer vision (CV) in higher education. CV integrated with mobile applications can enhance student monitoring, prevent academic dishonesty, and improve campus safety (Rubaiya Tasnim Sholi et al., 2024). Additionally, technologies such as natural language understanding, CV, and biometrics are increasingly being recognized as crucial in higher education settings (J. Wang, 2024). In STEM education, CV algorithms have proven effective in augmenting self-study models by monitoring student engagement and generating personalized learning pathways (Abdrakhmanov et al., 2024). Moreover, the COVID-19 pandemic has accelerated the integration of CV technologies in Ukrainian higher education, with a focus on deep neural networks and defense-related projects (Yesilevskyi & Kyt, 2024).

Research has shown that computer vision can have a significant impact on student engagement, learning outcomes, and operational efficiency. (Aboobaker & K.H, 2022) found that computer self-efficacy and intrinsic learning motivation positively influence learning engagement, with computer self-efficacy having a more substantial impact. (Ali Kadhim, 2020) further supported this, suggesting that digital games, web conferencing, and social media can enhance student engagement. (Pirker et al., 2021) highlighted the potential of virtual reality in computer science education, showing that it can lead to higher presence, absorption, flow, psychological immersion, and positive emotions. (Wekerle et al., 2020) emphasized the importance of using digital technology to promote higher education learning, particularly through constructive and interactive activities, which can be facilitated by computer vision. These findings collectively suggest that computer vision can play a crucial role in enhancing student engagement, learning outcomes, and operational efficiency.

4. Trends And Future Directions

A. Emerging Trends

Recent advancements in computer vision in higher education have been shaped by the integration of virtual and augmented reality (VR/AR) technologies, which have transformed the learning experience (Xanthidis et al., 2020). This transformation has also influenced the training of future computer science teachers, with a focus on computer literacy, interactive technologies, and practical skills (Verbovskyi & Melnyk, 2023). The potential of computer vision in predicting graphics for learning-by-doing has been explored, particularly in the context of architectural learning (M. Li et al., 2022). Additionally, the construction of computer courses in higher vocational education has been discussed, emphasizing the enhancement of teaching quality and students' overall abilities (Run, 2022). These trends collectively point to a future in which computer vision plays a central role in transforming the educational experience, from the classroom to the virtual world.

B. Challenges and Ethical Considerations

The implementation of computer vision technologies presents various challenges, limitations, and ethical concerns. These include concerns about the impact on the user's self and the potential for new forms of hacking (Sample et al., 2020), the need for clear ethics and safety guidelines in virtual learning environments (Steele et al., 2020), barriers to incorporating ethics into computing education (Smith et al., 2022), and the ethical questions raised by AI-supported mentoring in higher education (Köbis & Mehner, 2021). These issues highlight the importance of considering the ethical implications of these technologies and the need for further research and development of appropriate guidelines.

C. Potential Future Applications

The integration of computer vision in higher education is a rapidly evolving field, with potential applications in bespoke learning, intelligent tutoring systems, collaboration facilitation, and automated grading (Crompton & Burke, 2023). This trend is particularly evident in engineering education, where frameworks are being designed to enhance student performance and the teaching-learning process (Rawat & Sood, 2021). However, there is a need for increased awareness of the potential of computer vision in education, particularly in environments like Saudi Arabia (Aldosari, 2020). The use of computer vision in higher education also presents ethical implications and challenges, which need to be carefully considered (Moreno-Marcos et al., 2020).

A study on primary school children found that an educational pamphlet significantly increased their knowledge of computer vision syndrome (Manjusha A Y, 2023). This is particularly relevant given the increasing use of computers in education. Another study identified problem-solving, math, and programming skills as core competencies for computer science education in K-12 schools (Zhu & Wang, 2023). The severity of computer vision syndrome in workers was found to be associated with a healthy lifestyle and dry eye condition (C. Wang et al., 2023), highlighting the importance of addressing these factors in higher education. Lastly, the prevalence of computer vision syndrome among undergraduate and medical students has increased during the COVID-19 pandemic, suggesting a need for better management strategies (C. Wang et al., 2023).

D. Recent Showed-Up Limitations

The use of chatbots in higher education, particularly generative chatbots like ChatGPT, presents both potential and limitations. While these chatbots can enhance interactivity and provide real-time feedback, they also raise ethical concerns such as privacy, algorithmic bias, and plagiarism (Currie, 2023)(Williams, 2024). Despite these limitations, they can still be valuable tools for improving productivity and learning efficiency, as long as users remain critical and selective in their use (Firaina & Sulisworo, 2023). Further research is needed to fully understand the impact and potential of chatbots in higher education.

5. Contextualizing In The Moroccan Higher Education Landscape

The landscape of computer vision adoption and innovation in Moroccan higher education is shaped by a range of factors. (Bouchra, 2020) emphasizes the need for educational innovation, with a focus on "Design Thinking" as an agile approach. (Tamer & Knidiri, 2023) further underscores the importance of digital transformation, including the integration of technologies like computer vision. (Zidoun & Zary, 2021) and (Dehbi et al., 2023) both highlight the positive perceptions and innovative use of mobile learning among Moroccan instructors and students, suggesting a receptiveness to technological advancements. These studies collectively suggest a growing openness to the adoption of computer vision and other advanced technologies in Moroccan higher education.

The integration of computer vision in Moroccan educational settings is a growing trend, with a focus on language learning strategies (Asserraji, 2020), Building Information Modelling (BIM) in higher education (Shibani et al., 2020), and the use of digital tools in a pedagogical meta-model (Chergui et al., 2020). However, the implementation of these technologies is hindered by challenges such as a lack of infrastructure and technological readiness (Anigri, 2021). Despite these challenges, there is a clear push towards the digitalization of the educational system in Morocco, with a particular emphasis on the use of technology in language learning and the development of smart universities.

Always in the context of ethical considerations, Williams (Williams, 2024) and (Zeb et al., 2024) both highlight the potential for algorithmic bias, privacy concerns, and academic dishonesty, emphasizing the need for clear policies, advanced plagiarism detection techniques, and innovative assessment methods. (Zahari Md Rodzi et al., 2024) further underscores the importance of strong data protection measures and ethical practices in AI implementation, particularly in addressing privacy and security concerns. Lastly, (Kumari et al., 2023) emphasize the role of digital citizenship education in preparing students to become responsible and informed digital citizens, which is crucial in the ethical use of computer vision in higher education.

Conclusion

The comprehensive exploration of computer vision's integration within higher education illuminates its profound impact on the present and future of learning environments. The amalgamation of computer vision with educational paradigms signifies a transformative leap toward innovation, efficiency, and inclusivity in academia.

As evidenced by the myriad applications across learning enhancement, teaching support, campus management, research and development, accessibility, collaboration, and skill development, computer vision emerges as a catalyst for revolutionizing pedagogical approaches. Its integration augments traditional educational materials with immersive, interactive elements, personalized learning experiences, and streamlined administrative processes. Moreover, its role in fostering inclusivity for differently-abled learners and facilitating seamless collaboration in virtual spaces underscores its potential for creating equitable learning environments.

The article's of emerging trends and future trajectories unveils a horizon brimming with possibilities. However, alongside its promise, ethical considerations and challenges necessitate a nuanced approach to implementation. Striking a balance between technological advancement and ethical responsibility remains imperative in harnessing the full potential of computer vision in education. As AI continues to evolve, academic institutions must not only focus on the implementation of these technologies but also ensure that ethical considerations are at the forefront of their strategies. Future research must address the long-term implications of AI in education, as highlighted by (H N et al., 2024).

Moreover, within the Moroccan higher education landscape, the receptiveness to digital transformation underscores a promising trajectory, albeit with infrastructural challenges that require attention. The integration of computer vision technologies within this context mirrors a broader global trend toward embracing innovation while navigating the complexities of technological readiness.

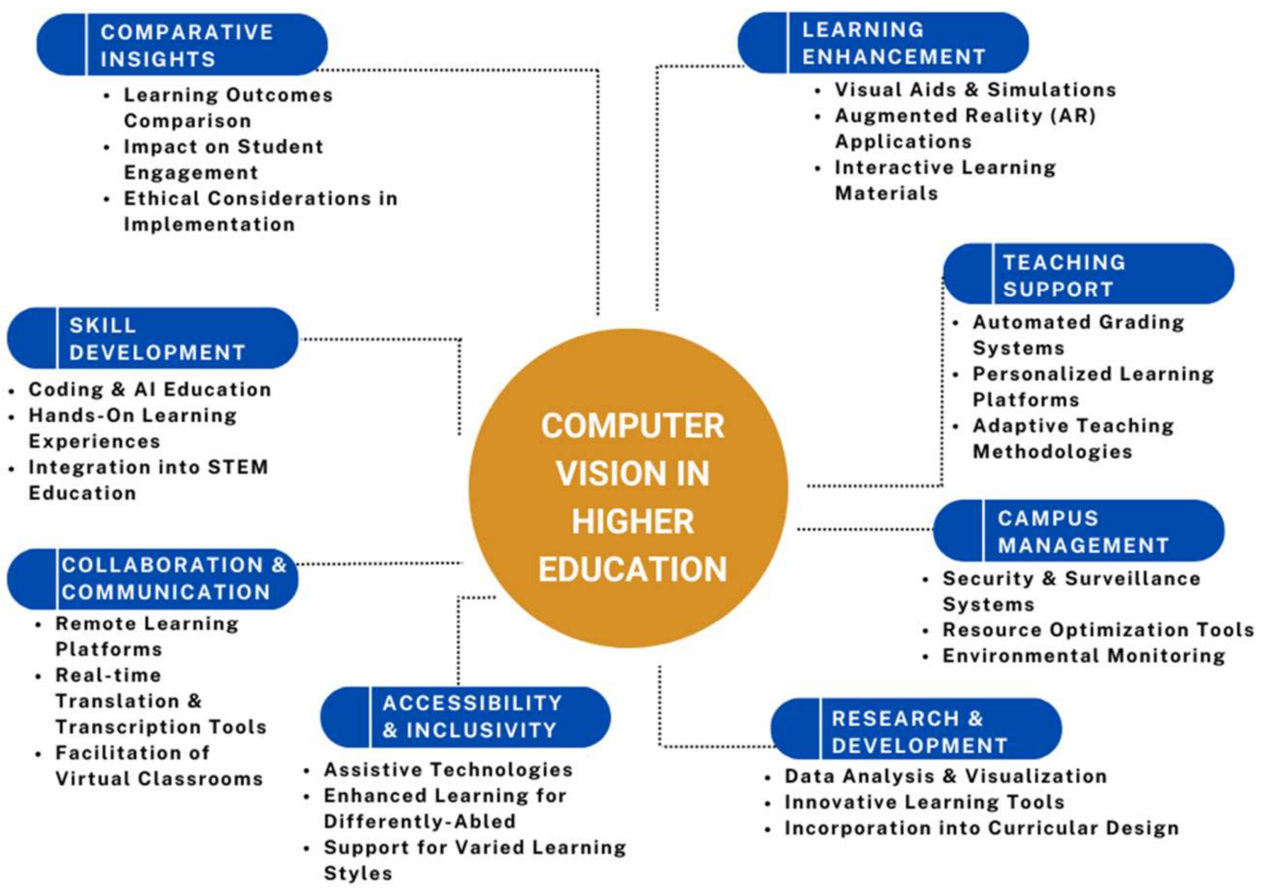

Fig. 3 : Interconnected Elements of Computer Vision in Higher Education

In essence, the article serves as a testament to the transformative power of computer vision, urging stakeholders within higher education to embrace its potential, address challenges, and chart a path toward a future where technology harmoniously enriches the educational journey. As the educational landscape evolves, the symbiotic relationship between technology and pedagogy, when nurtured thoughtfully, holds the key to sculpting an inclusive, adaptive, and visionary educational ecosystem.

The visual summary in "Fig. 3" encapsulates the wide-ranging applications of computer vision in higher education, spanning from learning enhancement and teaching support to skill development and campus management. This interconnected framework highlights the various domains where computer vision technologies are making a significant impact, enabling personalized, immersive, and inclusive educational experiences.

In summary, the article illuminates the groundbreaking potential of computer vision technologies, presenting a panoramic view of their applications and future trajectories in reshaping the landscape of higher education. Moreover, the article extrapolates the trends and future directions of computer vision in higher education, emphasizing emerging technologies, ethical considerations, and the potential for bespoke learning experiences. However, amidst the promise of innovation, careful attention must be given to the ethical considerations and challenges that accompany the integration of computer vision technologies. The ethical implications of algorithmic biases, data privacy concerns, and the equitable distribution of technological resources demand our utmost attention. Striking a delicate balance between technological advancement and ethical responsibility is paramount in ensuring that the transformative potential of computer vision is harnessed for the collective good.

Looking to the future, the trajectory of computer vision in higher education is poised for continued growth and evolution. Emerging trends such as personalized learning, adaptive teaching methodologies, and collaborative learning environments hold promise for ushering in a new era of educational excellence. However, realizing this vision requires collective effort, collaboration, and a shared commitment to harnessing technology for the betterment of society.

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