УДК 004.8+004.92]:331.5:37.018.43 DOI: 10.31673/2412-4338.2025.048925

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ADAPTING EDUCATION TO THE 3D GRAPHICS MARKET USING AI

Abstract. *The article examines the application of artificial intelligence and chatbots in the field of career counseling and education, with a focus on the specific challenges of their implementation in the 3D graphics industry. Particular attention is paid to analyzing the information asymmetry between educational programs and the rapidly dynamic labor market, which is driven by the rapid development of 3D modeling, visualization, generative design, and real-time tools. The growing demand for proficiency in tools (Unreal Engine, Unity, Blender), Python automation skills, and integration with LLM models creates significant challenges for students, entry-level professionals, and educators, who require constant access to up-to-date market analytics to adjust professional development and update curricula.*

To address these challenges, a solution based on NLP and machine learning methods is proposed — the prototype of the Telegram assistant AI Job. Its functionality includes aggregating vacancies from open sources, automatically analyzing skill requirements, identifying qualification gaps (skill gaps), and generating personalized recommendations for users. Thus, the system serves as a career navigator, vacancy aggregator, skill analyst, and teaching assistant. The prototype is implemented using the asynchronous Python framework Aiogram 3+, ensuring high performance, stability, and modular architecture. The bot performs multi-channel vacancy parsing, automatic AI user testing, resume analysis, qualification level classification (Junior/Middle/Senior), and generates personalized daily digests. The system's analytical reports allow educators to track current market trends and timely update the content of educational disciplines in accordance with industry needs.

Pilot testing of the system involving students, young professionals, and educators from the fields of 3D graphics, game design, and digital design demonstrated a positive impact on users' labor market orientation and increased their motivation to build individual educational trajectories. The obtained results confirm the system's potential as a tool for operational labor market monitoring, educational path formation, and enhancing the relevance of educational content in dynamic technological industries.

Keywords: *3D graphics; artificial intelligence; AI tools; career guidance; information system; monitoring; educational trajectories; curriculum adaptation.*

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АДАПТАЦІЯ ОСВІТИ ДО РИНКУ 3D-ГРАФІКИ ЗА ДОПОМОГОЮ ШІ

Анотація. *У статті досліджується застосування штучного інтелекту та чат-ботів у сфері кар'єрного консультування та освіти, з акцентом на специфічні проблеми їх впровадження в галузі 3D-графіки. Окрема увага приділена аналізу інформаційної асиметрії між навчальними програмами та стрімко динамічним ринком праці, що зумовлено швидким розвитком технологій 3D-моделювання, візуалізації, генеративного дизайну та інструментів реального часу. Зростання попиту на володіння інструментами (Unreal Engine, Unity, Blender), навичками Python-автоматизації та інтеграції з LLM-моделями створює суттєві виклики для студентів, початкових фахівців та викладачів, які потребують постійного доступу до актуальної ринкової аналітики для корекції професійного розвитку та оновлення навчальних курсів.*

Для подолання цих викликів запропоновано рішення на базі методів NLP та машинного навчання — прототип Telegram-асистента AI_Job. Його функціонал включає агрегацію вакансій з відкритих джерел, автоматичний аналіз вимог до навичок, ідентифікацію прогалин у кваліфікації (skill gaps) та генерацію персоналізованих рекомендацій для користувачів. Таким чином, система виконує роль кар'єрного навігатора, агрегатора вакансій, аналітика навичок і помічника викладача. Реалізація прототипу здійснена на базі асинхронного Python-фреймворку Aiogram 3+, що забезпечує високу продуктивність, стабільність і модульність архітектури. Бот здійснює багатоканальний парсинг вакансій, автоматичне AI-тестування користувачів, аналіз резюме, класифікацію рівня кваліфікації (Junior/Middle/Senior) та формування персоналізованих щоденних дайджестів. Аналітичні звіти системи дозволяють викладачам відстежувати актуальні ринкові тенденції та своєчасно оновлювати зміст навчальних дисциплін відповідно до потреб індустрії. Пілотне тестування системи за участі студентів, молодих фахівців та викладачів з галузей 3D-графіки, геймдизайну та цифрового дизайну продемонструвало позитивний вплив на орієнтацію користувачів на ринку праці та підвищило їх мотивацію до побудови індивідуальних освітніх траєкторій. Отримані результати підтверджують потенціал системи як інструменту для оперативного моніторингу ринку праці, формування освітніх шляхів та підвищення релевантності навчального контенту в динамічних технологічних галузях.

Ключові слова: *3D-графіка; штучний інтелект; AI-інструменти, професійна орієнтація; інформаційна система, моніторинг, освітні траєкторії; адаптація навчальних програм.*

Problem statement.

Over the past few decades, the rapid development of digital technologies and computer graphics has significantly transformed the labour market in the field of 3D graphics. The demand for content for games, film, VR/AR, and advertising constantly updates the requirements for professionals, creating both opportunities and challenges for specialists and educational institutions. The traditional career guidance system, relying on outdated data, cannot keep up with this dynamism. The difficulties lie in tracking the current demands of employers, adjusting skill sets, and mastering new software tools. The emergence of generative AI further intensifies the need to update curricula and teaching methods.

The growing demand for qualified 3D specialists makes the search for effective tools for market analysis and learning support an urgent issue. Intelligent systems capable of processing large volumes of data in real time play a key role here. The application of AI (NLP, machine learning) for job vacancy analysis allows for the automatic identification of key competencies, the formation of personalised learning trajectories, and the adaptation of educational programmes. As an example, the CareerPooler system uses generative AI and metaphorical visualisation in the form of a billiard table, where balls symbolise skills and decisions, and their interaction visually demonstrates the complexity and non-linearity of career paths. The use of a visual narrative metaphor combined with physical simulation promotes a deeper understanding of the instability of professional trajectories and the formation of adaptive learning strategies. CareerPooler demonstrates the potential of generative AI as a tool for supporting self-reflection and individualised educational planning [1]. However, the CareerPooler system does not directly explore the field of 3D graphics.

3D graphics are rapidly evolving, causing students to be unsure of which skills to focus on and educational programmes to lag behind the market. To bridge this gap, the development of an AI-powered chatbot that provides personalised recommendations on skills and career trajectories is a relevant solution. Such a tool would provide both students and educational institutions with timely analytical data for making informed decisions.

Analysis of recent research and publications.

In recent years, there has been an active integration of AI technologies into various fields, including education, career counselling, and the labour market. Consequently, recent scientific publications have seen a growing number of works dedicated to the use of chatbots and AI for supporting education, career guidance, and user interaction. However, their application in highly specialized niches, such as 3D graphics and the analysis of job vacancies in this sphere, remains insufficiently researched.

Within the study of the educational potential of artificial intelligence-based chatbots, attention should be paid to systematic reviews conducted by L. Labadze, M. Grigolia, and L. Machaidze [2], C. V. Okonkwo and A. Ade-Ibijola [3], as well as M. A. Kuhail, N. Alturki, S. Alramlawi, and K. Alhejori [4]. All three works summarize modern approaches to implementing AI chatbots in higher education, focusing on their role in student support, optimizing the learning process, and personalizing the educational environment.

According to the conclusions of study [2], students most frequently use chatbots as tools for homework assistance, personalized learning, and skill development, while educators value them for saving time and supporting educational activities. The authors also highlight challenges related to the accuracy, ethics, and reliability of responses provided by chatbots.

In work [3], a classification of educational chatbots was carried out based on functional features (informational, educational, administrative, motivational), technology types (rule-based, NLP, ML), and educational contexts (higher education, distance learning, student support). The authors emphasize the importance of pedagogical design and the integration of chatbots into the learning environment to achieve a positive impact on learning outcomes.

In the study [4], the authors conducted a systematic review of 36 scientific publications dedicated to user interaction with educational chatbots. The analysis covers seven key dimensions: application domains, platforms, design principles, roles of chatbots, interaction styles, empirical evidence, and limitations. It was established that chatbots are most commonly used in the fields of computer science, general education, language learning, engineering, and mathematics. They perform functions as virtual teachers or learning partners, promoting student engagement and personalization of the educational process.

The issues of developing and implementing AI-based chatbots for career counselling in various social and technological contexts have been explored in their works by N. Suresh, the British company specializing in providing career services using AI CareerChat UK [6], as well as N. M. Rangji, B. Rao, and C. Lipizzi [7].

Report [6] presents a case study of the CiCi chatbot, developed in the UK to provide 24/7 career support, helping young people navigate career choices, education, and employment. The system uses natural language processing and adaptive dialogue logic, providing access to information about learning, professions, and employment. The authors emphasize the role of the CiCi chatbot in enhancing user motivation, self-esteem, and awareness, as well as in supporting national educational policy. The report demonstrates an example of large-scale AI chatbot implementation in the public sector.

In study [7], the Steve platform is proposed – a chatbot based on Large Language Models (LLMs) that conducts AI interviews to assess a user's career level and generate personalized learning recommendations. The authors implemented a modular architecture using the OpenAI API, allowing the system to be adapted to various industries. A distinctive feature of the work is the combination of qualitative and quantitative evaluation methods, as well as the integration of PDF resumes as input data. The platform demonstrates potential for scalable use in HR systems and professional education.

The aim of the article is to explore the possibilities of using AI for analyzing the labor market in the field of 3D graphics and developing a prototype of an intelligent Telegram assistant, AI_Job, as a tool to support the career guidance of students, young professionals, and educators.

The research is focused on overcoming the information asymmetry between the educational process and market dynamics, supporting the career orientation of students and young professionals, and providing educators with analytical tools to adapt curricula to current industry requirements.

RESEARCH METHODOLOGY

To achieve the set goal, an applied study was conducted, comprising analytical, design, and empirical stages. Each had clearly defined tasks, implementation methods, and expected results aimed at testing the effectiveness of the AI_Job intelligent chatbot prototype for analyzing the labor market in 3D graphics and supporting career guidance.

At the analytical stage, a systematic review of scientific sources, international reports (OECD [10], UNESCO [11], WEF [12]), and job platform data (Lightcast [13], Burning Glass Technologies [9]) was conducted. This allowed for the identification of key trends in the structure of in-demand skills, technological advancements, and the specifics of the 3D graphics professional ecosystem. It was established that the labor market demonstrates a shift towards a skill-based hiring model, growing demand for real-time tools, generative systems, and the integration of DCC (Digital Content Creation) packages with LLM (Large Language Model) technologies.

The design stage involved the development of the AI_Job Telegram assistant prototype, built on the Python framework Aiogram 3+. The system architecture includes modules for vacancy parsing, resume analysis, AI-based testing, user level classification, statistical report generation, and daily newsletters. The bot

utilizes NLP, ML, and LLM technologies for automated processing of text data, generating personalized recommendations, and assisting educators in revising curricula.

The empirical stage of the research encompassed surveys and pilot testing of the prototype among the target audience—students, young professionals, and educators whose activities are related to the fields of 3D graphics, game design, and digital design. The study was conducted at Borys Grinchenko Kyiv Metropolitan University, involving a sample of 3rd and 4th-year students. Additionally, young professionals—university graduates who recently began their professional careers in 3D graphics and game design—were engaged. In total, surveys and interviews of 34 respondents were conducted, allowing for the evaluation of the system's effectiveness based on the following criteria: ease of job search, accuracy of professional self-identification, and usefulness of analytics for updating educational content. The Google Forms platform served as the data collection tool, enabling automatic generation of statistical reports. Quantitative results were converted into percentages for further analysis.

This article highlights only specific aspects of the research, including data collection methods, the chatbot structure, pilot testing results, and the benefits of using intelligent systems to support educational adaptation in the field of 3D graphics.

RESEARCH RESULTS

The rapid transformation of the labor market under the influence of AI and real-time technologies in 3D environments (game/VFX/XR/CAE) causes dynamic changes in competency profiles and requirements for entry-level specialists. Current international employer reports confirm accelerated growth in demand for digital and data-oriented skills, the ability to work with intelligent systems, as well as for professional roles related to the creation and support of real-time 3D content, visualization, and simulation. Analytical forecasts indicate that these trends will persist in the medium term for 2025–2030 [12]. The Lightcast publication [13] analyzes the transformation of the labor market under the influence of cutting-edge technologies (artificial intelligence, XR, 3D visualization, and simulations) and highlights how these changes shape new requirements for professional skills and competencies. Analysis of job vacancy data from the Lightcast platform reveals that demand for 3D skills is growing at rates exceeding the average market indicators. At the same time, the structure of in-demand competencies is undergoing significant changes due to the emergence of new engines, production pipelines, and generative tools. In particular, there is a trend of integrating traditional DCC (Digital Content Creation) packages with services based on Large Language Models (LLMs) and diffusion systems, forming a new type of professional profile for specialists in 3D graphics. Concurrently, modern educational policy requires the implementation of tools capable of promptly adapting educational content to current industry demand. International organizations – particularly the OECD and UNESCO – directly encourage the use of AI technologies to improve alignment between educational programs and labor market needs, while emphasizing the principles of transparency, ethics, and data quality [10], [11].

It should be noted that validated approaches for aligning curricula with the job market based on Natural Language Processing (NLP) methods and vector representations – specifically topic modeling and sentence embeddings – are described in the scientific literature. However, universities lack practical, day-to-day tools that would make such analytics accessible to educators, students, and career centers [14].

The current labor market for 3D specialists is characterized by a gradual shift from a "diploma-centric" to a skill-based hiring model, which requires flexible learning formats such as micro-certificates and bootcamps. Despite the rapid increase in demand, the market remains dynamic and fragmented, creating an information gap between current employer requirements and the ability of students and educational institutions to analyze them promptly.

An effective solution is the use of artificial intelligence (AI), particularly chatbots based on Natural Language Processing (NLP) and Machine Learning (ML) technologies, which can automatically analyze job vacancies, extract key requirements, and generate personalized recommendations for different target groups. In our view, the development of such an intelligent chatbot will enable:

– **For students** – the ability to see current requirements for 3D specialists and form personalized educational trajectories.

– **For young professionals** – quick search for relevant job vacancies based on their existing skills.

– **For educators** – quick access to market analytics for adjusting curricula.

The system is implemented in Python using the Aiogram 3+ framework, which provides asynchronicity, stability, and easy integration with the Telegram API. The architecture includes the following main modules:

– `bot.py` – user interaction logic;

– `parsers.py` – collection of vacancies from open sources (Behance Jobs, Dribbble, LinkedIn) via the `search_all()` function;

– `ai_module.py` – natural language processing, resume analysis, assessment of test answers via the OpenAI API;
– `storage.py` – local `jobbot.sqlite` database for storing users, vacancies, and states;
– Statistical module (`stats/`) – automatic generation of daily CSV summaries for analytics;
– `logs/` – detailed event logs.

The system operates on a state machine principle, where each user action (updating a profile, taking a test, completing a survey) is recorded as a separate state. This ensures the bot maintains context and responds to commands sequentially.

The principles of the job search system's operation through the chatbot are designed to ensure maximum convenience and effectiveness for the user at every stage of interaction with the platform.

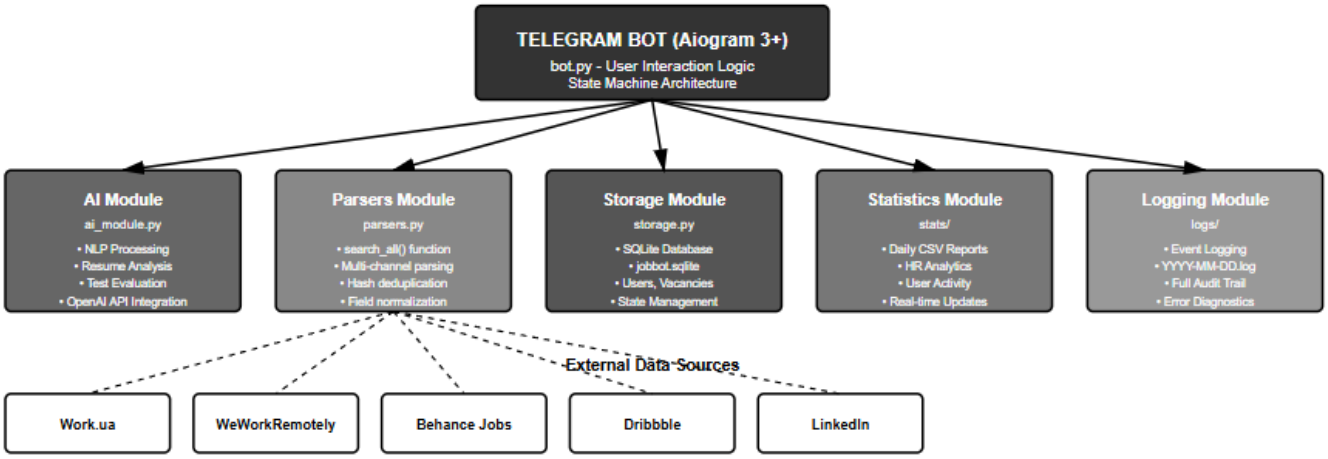

Fig. 1. Telegram bot structure

The interface is minimalist and intuitive: each command is represented by a button on the Telegram keyboard and includes an emoji hint. Inline buttons in the profile allow for data updates without returning to the main menu. The user immediately sees a vacancy card with a link and a preview description, which reduces the number of clicks and encourages faster responses to job offers.

As part of the research on the application of artificial intelligence technologies for labor market analysis as a tool to support career guidance and educational adaptation, a pilot test of the AI_Job Telegram assistant prototype was conducted. Thirty-four respondents – students, young professionals, and educators – participated in the trial. The survey results showed that:

• 87% of respondents noted a significant reduction in time spent searching for vacancies;
• 72% of students were able to more accurately define their professional profile after taking the AI-powered test;
• 63% of educators recognized the practical value of real-time monitoring of employer demands and required software skills when updating curricula.

It should be noted that the data presented in the graph (Fig. 2) summarize the responses to specific key questions that were part of a broader survey aimed at studying the effectiveness of applying AI tools in the field of 3D graphics. The survey covered a wider range of topics, including aspects of career guidance, adaptation of educational programs to labor market demands, and the perception of digital solutions among students, young professionals, and educators.

The obtained data can serve as an empirical basis for adapting educational programs in the fields of 3D graphics and multimedia. They also confirm the effectiveness of the proposed architecture and the appropriateness of using chatbots as a career guidance tool, along with the feasibility of expanding their functional capabilities.

Thanks to its ability to provide analytical data, the bot can become an effective tool for adapting curricula to meet modern labor market demands. By using real job vacancy data and skill development forecasts, educators will be able to promptly update syllabi, and universities can adjust educational strategies based on current trends. This, in turn, facilitates the implementation of recommendations from international organizations, such as the OECD, on using AI to improve the quality and relevance of education. It also supports policies aimed at enhancing graduate employability and competitiveness.

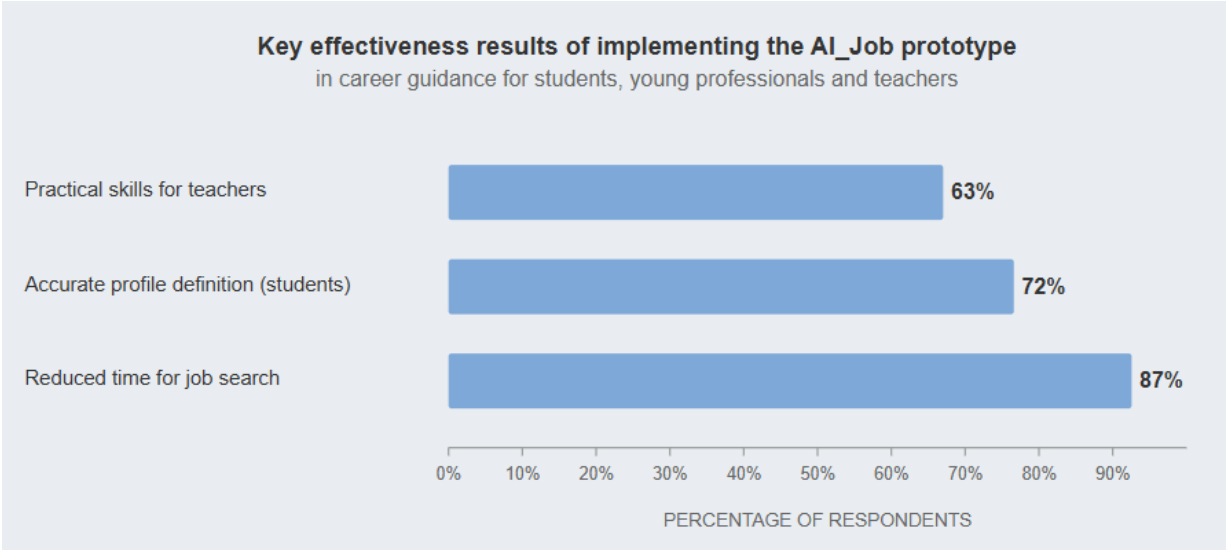

Fig. 2. Statistical survey data from students, young professionals, and educators on assessing the effectiveness of the AI_Job Telegram assistant prototype as a career guidance tool in the field of 3D graphics.

CONCLUSIONS AND PROSPECTS FOR FURTHER RESEARCH

The study confirmed the feasibility of using artificial intelligence and chatbots for the automated analysis of the labor market in the field of 3D graphics. The proposed AI chatbot prototype, AI_Job, demonstrated its ability to provide students, young professionals, and educators with up-to-date information on employer requirements, thereby supporting career guidance and the modernization of educational programs.

The results of the pilot test indicate a significant practical impact: 87% of respondents noted a reduction in the time spent searching for vacancies, 72% of students reported improved professional self-identification, and 63% of educators found the obtained analytical data useful for updating curricula. The chatbot effectively aggregates job postings, identifies skill gaps, and generates personalized recommendations, thereby enhancing the alignment between market demands and educational content. The obtained results demonstrate the high potential of AI for monitoring technological trends and supporting career guidance. The use of machine learning and natural language processing methods ensures the rapid and accurate identification of relevant competencies, which is critically important for the timely updating of educational programs and equipping graduates with relevant skills.

Thus, the application of intelligent systems significantly enhances the quality of career guidance and facilitates the adaptation of educational programs to dynamic changes in the labor market for 3D graphics. This opens prospects for the further development of interactive educational technologies and the implementation of innovative AI tools in higher education and professional training.

It is also important to note that the developed AI_Job Telegram assistant prototype is already operational but continues to undergo system improvement. This involves expanding industry-specific vocabulary, generating more personalized recommendations for students and young professionals, integrating with portfolio platforms, optimizing skill assessment mechanisms, and adapting the model to related fields of digital design. Overall, the bot's architecture is flexible, scalable, and suitable for further development.

Further research may be directed toward studying the specifics of integrating various technological tools, such as Google Sheets, the Notion API, and LMS platforms, into the process of analyzing educational outcomes. This would ensure continuity of learning and adaptability to labor market changes, creating a flexible environment for lifelong self-development. Another important direction is the development of methodologies for implementing a web-based administrator panel for monitoring user activity, enabling the creation of individual career growth paths through analytics. Simultaneously, expanding the dictionary of 3D graphics industry terms will help improve the accuracy of professional training and job vacancy analysis. Development prospects also include creating an AI-based resume editor for auto-generating documents that meet employer requirements, as well as introducing gamification to motivate users in their professional development.

REFERENCES

1. Z. Wang, Z. Zeng, Y. Li, and Z. Ding, “CareerPooler: AI-powered metaphorical pool simulation improves experience and outcomes in career exploration,” *arXiv*, arXiv:2509.11461, 2025, doi: 10.48550/arXiv.2509.11461.
2. L. Labadze, M. Grigolia, and L. Machaidze, “Role of AI chatbots in education: systematic literature review,” *International Journal of Educational Technology in Higher Education*, vol. 20, no. 56, 2023. doi: 10.1186/s41239-023-00426-1.
3. C. W. Okonkwo and A. Ade-Ibijola, “Chatbots applications in education: A systematic review,” *Computers and Education: Artificial Intelligence*, vol. 2, p. 100033, 2021. doi: 10.1016/j.caeai.2021.100033.
4. M. A. Kuhail, N. Alturki, S. Alramlawi, and K. Alhejori, “Interacting with educational chatbots: A systematic review,” *Education and Information Technologies*, vol. 28, pp. 973–1018, 2023. doi: 10.1007/s10639-022-11177-3.
5. N. Suresh, N. Mukabe, V. Hashiyana, A. Limbo, and A. Hauwanga, “Career counseling chatbot on Facebook Messenger using AI,” in *Proc. Int. Conf. Data Sci., Mach. Learn. Artif. Intell. (DSMLAI)*, Windhoek, Namibia, 2021, pp. 65–73. doi:10.1145/3484824.3484875.
6. CareerChat UK, “CiCi, the 24/7 careers chatbot,” *OECD Observatory on Digital Technologies in Career Guidance for Youth*, May 2023. [Online]. Available: https://www.amazonfutureengineer.co.uk/
7. N. M. Renji, B. Rao, and C. Lipizzi, “Steve: LLM powered chatbot for career progression,” *arXiv*, arXiv:2504.03789, April 2025. [Online]. Available: https://arxiv.org/abs/2504.03789.
8. I. Mashkina, T. Nosenko, O. Hlushak, S. Spivak, and V. Bilous, “Optimizing customer support with AI chatbots: a case study,” *Cybersecurity: Education, Science, Technique*, vol. 4, no. 28, pp. 727–739, Jun. 2025. doi: 10.28925/2663-4023.2025.28.838.
9. L. Tenorio, “Demand for Unreal Engine and real-time 3D skills at all-time high,” *Unreal Engine*, May 2019. [Online]. Available: https://www.unrealengine.com/fr/blog/demand-for-unreal-engine-and-real-time-3d-skills-at-all-time-high.
10. OECD, *How Can Innovative Technologies Transform Vocational Education and Training?*, OECD Publishing, 2025. Available: https://www.oecd.org/en/publications/how-can-innovative-technologies-transform-vocational-education-and-training_fb40f416-en.html
11. UNESCO, “Why AI Belongs in Every Skills Classroom: Training TVET Educators for a Smarter Future,” *UNESCO*, August 2025. [Online]. Available: https://www.unesco.org/en/articles/why-ai-belongs-every-skills-classroom-training-tvet-educators-smarter-future.
12. World Economic Forum, *The Future of Jobs Report 2025*, Geneva, Switzerland, January 2025. [Online]. Available: https://reports.weforum.org/docs/WEF_Future_of_Jobs_Report_2025.pdf.
13. Lightcast, *Visualizing the Future. Demand for 3D Graphics and Real-time 3D Skills*, 2025. [Online]. Available: https://lightcast.io/resources/research/visualizing-the-future.
14. R. Yu, S. Das, S. Gurajada, K. Varshney, H. Raghavan, and C. Lastra-Anadon, “A Research Framework for Understanding Education-Occupation Alignment with NLP Techniques,” *Proc. 1st Workshop on NLP for Positive Impact*, Thailand, Aug. 2021, pp. 100–106. https://aclanthology.org/2021.nlp4posimpact-1.11.
15. Bondarchuk, A., Dibrivniy, O., Grebenyk, V., & Onyshchenko, V. Motion Vector Search Algorithm for Motion Compensation in Video Encoding. In: *IEEE 8th International Conference on Problems of Infocommunications, Science and Technology* . 2021. p. 345-348. doi: 10.1109/picst54195.2021.9772109
16. Shantyr, Anton, et al. Prediction of quality software quality indicators with applied modifications of integrated gradiates methods. *Informatyka, Automatyka, Pomiary w Gospodarce i Ochronie Środowiska*, 2025, 15.2: 139-146. https://doi.org/10.35784/iapgos.6892
17. M. Bone, E. G. Ehlinger, та F. Stephany, “Skills or degree? The rise of skill-based hiring for AI and green jobs,” *Technological Forecasting and Social Change*, vol. 214, Art. 124042, May 2025, doi: 10.1016/j.techfore.2025.124042.