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Toward the improvement of teaching in object-oriented programming: the integration of intelligent chatbot assistance and professor Alex's implementation

Hacia la mejora de la enseñanza en programación orientada a objetos: la integración de la asistencia de chatbot inteligente y la implementación del profesor Alex

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Abstract: In education, chatbots provide personalized learning, instant feedback, and accessible support, enhancing student engagement and understanding across various academic subjects. This study investigates the deployment of a chatbot on the SnatchBot platform, integrated with Telegram, to assist university students in Object-Oriented Programming (OOP). The development of the chatbot included defining objectives, designing its personality, selecting tools, and creating a conversation flow using natural language processing (NLP). Assessed through surveys, the chatbot, named Profe Alex, significantly enhanced student autonomy in OOP by providing concepts, quizzes, and code examples. A survey revealed that 90% of the users positively rated the tool, confirming its effectiveness in OOP instruction. The findings indicate substantial potential for chatbots as educational tools in computer science and point towards a broader application of AI in education.

Keywords: Chatbot, object-oriented programming, artificial intelligence, chatbots in education.

Resumen: Los chatbots en la educación ofrecen aprendizaje personalizado, retroalimentación instantánea y soporte accesible, mejorando el compromiso y la comprensión de los estudiantes en diversos temas académicos. Este estudio explora el uso de un chatbot, implementado en la plataforma SnatchBot e integrado con Telegram, para asistir a estudiantes universitarios en Programación Orientada a Objetos (POO). El desarrollo del chatbot incluyó la definición de objetivos, diseño de personalidad, selección de herramientas, y la creación de un flujo de conversación mediante procesamiento de lenguaje natural (PLN). Evaluado a través de encuestas, el chatbot, denominado Profe Alex,

mejoró significativamente la autonomía de los estudiantes en POO, proporcionando conceptos, cuestionarios y ejemplos de código. Una encuesta mostró que el 90% de los usuarios valoró positivamente la herramienta, confirmando su eficacia en la enseñanza de POO. Los resultados sugieren un potencial significativo de los chatbots como herramientas educativas en ciencias de la computación y apuntan hacia una mayor aplicación de la IA en educación.

Palabras clave: Chatbot, programación orientada a objetos, inteligencia artificial, chatbots en educación.

1. INTRODUCTION

Recent advancements in disruptive technologies, particularly Artificial Intelligence (AI), have significantly improved learning environments by integrating advanced technologies with pedagogical strategies. AI, particularly through chatbots, can offers personalized learning experiences, enhancing student engagement in various academic disciplines, including the field of object-oriented programming (OOP) [1], [2]. The chatbots, leveraging Natural Language Processing (NLP) and Understanding (NLU), emulating human conversation to provide intuitive and responsive educational support [3]-[5].

The general application of chatbots across sectors such as customer support and online commerce demonstrates their versatility and autonomy in performing tasks without human intervention [6]-[10]. Development tools and platforms like Microsoft Bot Framework, Botpress, and Dialogflow enable the creation of chatbots with diverse functionalities, including natural language understanding and integration with external systems [11]-[15].

In education, chatbots serve as innovative tools, aiding in teaching languages, enhancing learning through gamification, and offering sophisticated support in higher education, particularly in challenging subjects like OOP [16]-[20].

This work describes the development of "Profe Alex," a chatbot designed to assist university students with OOP, aiming to provide continuous support, and introduce innovative technologies. The specific objectives of this study are to evaluate the effectiveness of "Profe Alex" in enhancing students' understanding of OOP, to improve engagement, and to explore the impact of the chatbot's personality on learning outcomes. It emphasizes the chatbot's potential in delivering effective information and services and exploring the impact of its personality on user experience and educational outcomes in complex subjects [21], [22].

The development involved several key phases: defining the bot's objectives, characterizing its personality, selecting the appropriate development framework, elaborating a conversational schema, and implementing the system, all geared towards enhancing user interaction and educational outcomes.

This article is the completion of a project entitled 'Chatbot as an Intelligent Personal Assistant for OOP Learning'. The paper is structured as: Section 2 outlines the methodology utilized for the development of the study, followed by the demonstration of our Bot's implementation and findings in Section 3. Lastly, we provide our concluding remarks.

2. PREVIOUS WORKS

We proposed a general taxonomy of a set of works reported to the literature. Our proposed taxonomy groups these works into four categories. Applications and Impact; explores chatbots enhancing educational engagement and personalized learning. Design, Development, and Implementation Challenges; address the challenges in creating effective educational chatbots, emphasizing ethical and technical considerations. Evaluation and Effectiveness; assesses chatbots' impacts on learning outcomes and motivation. Future Directions and Ethical Considerations; delve into the potential and ethical use of AI in education, highlighting the need for responsible technology integration and future research avenues.

2.1. Applications and impact of AI chatbots in education

Studies highlight chatbots as key in restructuring teaching methodologies, offering personalized

support, and addressing traditional educational challenges. In [23], underline chatbots' multifaceted benefits, including immediate homework assistance, personalized learning pathways, and efficiency gains for educators. Further investigation, as seen in works like [24], examines the dynamic interactions between learners and chatbots, emphasizing the enhancement of personalized and immersive educational experiences. Empirical evidence, particularly from [25]-[26], demonstrates chatbots' positive effects on student performance, with specific studies like [27] exploring differential engagement outcomes among genders.

2.2. Design, development, and implementation challenges

In [28], the development of Educational Conversational Agents (ECAs) is presented as a complex endeavor encompassing design, development, and implementation. The initial phase involves comprehensive research to collect relevant information on tools, methodologies, and requirements. This informs the specification phase, where learning goals and content are defined, leading to the customization of educational materials. The crucial design and implementation phase transitions from theory to practice, requiring thorough testing and student briefing on ECA usage.

The process concludes with an evaluation of the ECA's effectiveness, serving as a basis for future enhancements. This iterative methodology state the necessity for a detailed and flexible approach in overcoming the challenges associated with ECAs in education.

2.3. Evaluation and effectiveness of educational chatbots

Research into educational chatbots highlights their varied impact on student outcomes. In [29], a study on the effects of large language models (LLMs) on novice programmers found no significant impact on performance, suggesting cautious integration is advisable. In contrast, [30] revealed that chatbot-based micro-learning boosts intrinsic motivation among students in computer courses, despite similar performance levels to traditional methods, indicating potential for increased engagement. Furthermore, a meta-analysis in [31] aggregating results from 32 studies showed chatbots have a medium-to-high positive effect on learning outcomes like reasoning, achievement, and interest.

2.4. Future Directions and Ethical Considerations in Chatbot Integration

The address on the future and ethical considerations of chatbot integration in education, as discussed in recent literature, emphasizes the necessity for responsible AI use, transparency, and the mitigation of biases. Studies like [32] stress the importance of ethical frameworks and interdisciplinary efforts to enhance AI's educational impact while ensuring its ethical deployment. Another critical aspect, highlighted in [33], is the integration of AI chatbots to support self-regulated learning, highlighting the need for personalized learning experiences despite challenges such as biased information and the dissemination of inaccuracies.

Further, discussions in [34], [35] tackle the technical and ethical challenges posed by AI monopolies, suggesting improvements to make AI more accessible and efficient. Overall, the literature calls for a balanced approach to AI chatbot integration in education, emphasizing designs that align with educational principles and advocating for the responsible use of AI to enrich educational outcomes while addressing potential limitations and ethical dilemmas.

3. METHODOLOGY

The primary focus of this study revolves around the teaching and learning of Object-Oriented Programming (OOP) facilitated by a virtual chatbot assistant. Fig. 1, illustrates the phases that were undertaken for the development of these bots.

3.1. Defining the Bot’s Objectives

The initial phase involves defining the chatbot's objectives, crucial for guiding its development with precision and ensuring its relevance and effectiveness across all stages—from development to implementation and subsequent evaluation. This initial step is essential, establishing the strategic objectives that support the chatbot's intended purpose. Through analysis, the chatbot is envisioned to act as an instrumental resource in enhancing the pedagogical landscape of higher education, supported by a clearly articulated mission to improve learning objectives.

3.2. Characterization of the Bot’s Personality

Subsequent to objective setting, the delineation of the chatbot's personality becomes essential, serving

not only to humanize interactions but also to augment the tool's efficacy and user engagement. This phase necessitates an understanding of the target user demographic within educational contexts, fashioning a behavior that embodies accessibility, clarity, and responsiveness.

The personality of a chatbot significantly influences user interactions and communication strategies. Its traits influence how the chatbot responds, with specific word choices and tone reflecting these characteristics. For example, a friendly chatbot might use warm, encouraging language to make interactions feel more engaging. This intentional integration of personality traits is crucial for achieving educational outcomes and enhancing the user experience, making conversations seem more natural and significant, thereby increasing user satisfaction and engagement.

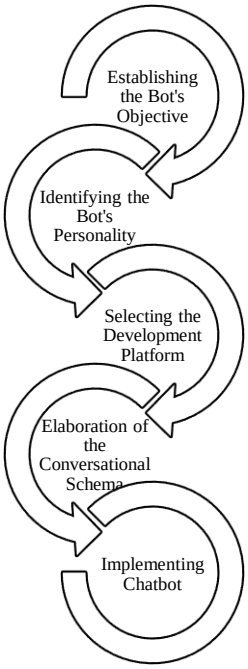

Fig. 1. *Phases of Chatbot Development. Source: Authors elaboration*

3.3. Selection of the Development Framework

In this phase, the choice of an appropriate development framework for the chatbot is determinant, as it must align with the bot's predefined functionalities and personality. The development path might involve the personalized construction of the chatbot utilizing a variety of programming languages, augmented by specialized design tools. Conversely, the adoption of a pre-established development platform could facilitate a more efficient creation process, offering access to templated designs and, in certain cases, sophisticated natural language processing (NLP) capabilities. A crucial decision at this stage involves assessing the necessity for the chatbot to embody adaptive learning features, necessitating the integration of advanced language models, machine learning algorithms, and appropriate deployment architectures.

3.4. Elaboration of the Conversational Schema

The delineation of a defined conversational schema is imperative, facilitating the bot's capacity to provide directional guidance to users, thereby sustaining engagement and adeptly resolving inquiries. A principal challenge within this domain is the anticipation of prospective conversational paradigms and the strategy of effective methodologies to address inquiries that may exhibit a lack of precision or deviate marginally from the central discourse. This challenge is of paramount importance within the ambit of chatbot design methodology, accentuating the necessity for the integration of Natural Language Processing (NLP) frameworks. The employment of NLP substantially augments the bot's proficiency in contextually understanding and reacting to a wide array of user inputs, inclusive of those characterized by nuanced variances or ambiguous articulations. The assimilation of advanced NLP strategies enables the chatbot to more precisely decode user inquiries, navigate through various conversational subtleties, and consequently elevate the overall interaction experience. This highlights the critical function of NLP in the refinement of the conversational schema and guarantees the chatbot's operational effectiveness across a spectrum of dynamic and multifaceted dialogic environments.

3.5. Implementing Chatbot

Within this phase, the implementation of the chatbot is operationalized, leveraging the previously delineated design, personality, and objectives. In this point, key components have been identified, encompassing pertinent topics, introductory greetings, positive reinforcement mechanisms, and strategies for addressing potential comprehension challenges encountered by the bot. Moreover, exhaustive testing involving end-users, alongside deployment assessments, will be undertaken to ascertain the chatbot's effectiveness and operational capabilities. This comprehensive evaluation process is crucial for confirming the chatbot's adherence to its intended functional specifications and its ability

to fulfill user expectations in real-world applications.

From the initial definition of the chatbot's objectives to the development of its conversational schema and personality, each phase must ensure the chatbot's effectiveness and relevance in an educational setting. The selection of a development framework and the integration of advanced NLP capabilities are pivotal in enabling the chatbot to deliver personalized, engaging, and contextually aware interactions.

4. RESULTS

4.1. Defining the Bot's Objectives

The purpose is to enhance the understanding of OOP through accessible exercises and resources, customizing learning to meet each student's needs to overcome specific OOP challenges and increase engagement. The chatbot, by providing constant support and feedback, contributes to an adaptable educational environment. Its integration with platforms like Telegram facilitates interactive and accessible learning, aiming to significantly improve academic performance in OOP and promote critical skills, including problem-solving and analytical thinking.

4.2. Characterization of the Bot's Personality

According to ChatBot's objectives, we have established some characteristics to model the personality of Profe Alex, it is presented in Table 1. Given his personality, the bot is an impetuous professor, however, he is always kind and respectful to his students. He is from Santa Marta – Colombia, and his main emotions are happiness, confusion, attention, and explanatory.

Table 1: *Design of chatbots Personality.*

Category and details	
Bot's Personality	Friendly, Respectful, Concrete, Receptive
Physical Characteristics	Name: Alex. Skin color: Brown. Hair color: Brown. Eye color: Brown. Objects: Glasses. Age: 35 years old. Height: 180 cm. City of birth: Santa Marta - Colombia
Body Expressions	Happy, Confused, Attentive, Explaining.

Source: *Authors elaboration.*

The personality traits selected for the bot were defined to align with the goal of teaching Object-Oriented Programming concepts. Traits such as being friendly, respectful, concrete, and receptive create a pleasant and motivating learning experience that facilitates student skill development. Emotions like happiness and confusion are suitable for educational interactions as they contribute to a more natural user experience. Moreover, physical characteristics and visual expressions add a realistic component related to the content or actions, such as being attentive and explanatory, that the bot performs in each iteration.

4.3. Selection of the Development Framework

In our study, we analyzed various platforms for developing chatbots, focusing on criteria like free access, NLP capabilities, language support, and social media deployment. DialogFlow and SnatchBot were initially selected based on these criteria. Subsequently, SnatchBot was chosen for its intuitive interface and diagram verification of bot flow. We utilized SnatchBot to develop our chatbot, structuring it around a series of interactions to facilitate user communication and functionality.

4.4. Elaboration of the Conversational Schema

It outlines the structured interactions of a chatbot designed to facilitate a user's use through a learning module (See Fig 2). It initiates with a 'Start' node, leading to the 'Presentation of the bot', where the bot introduces itself and outlines its capabilities and the utility it provides to the user. Following the introduction, there is a decision point where the user has the option to inquire about how to utilize the bot, prompting the bot to supply relevant information regarding its functionality. Subsequently, the user is directed to 'Topic #1', which represents the beginning of the educational content.

If the user expresses difficulty in understanding, the flow diverts to a clarification loop where the chatbot checks for the existence of the topic. If the topic exists, the chatbot will reiterate or clarify the topic. If the topic does not exist or if after clarification the user still does not understand, the chatbot will provide the option to start the course from the beginning or switch to a different topic. Upon successful comprehension of the topic, the user is assessed through a 'Exam or Quiz Questions' phase. The user's performance in this assessment dictates the subsequent path: if the user responds correctly, the flow progresses to the next topic. Otherwise, the topic is repeated for reinforcement.

This cyclical process of instruction and assessment continues until all topics are covered, at which point the chatbot engages in a 'Farewell' interaction before reaching the 'End' node, signifying the completion of the module.

4.5. Implementing Chatbot

In the proposed system architecture (see Fig. 3), a multi-layered approach integrates Telegram as the user interface, SnatchBot for session and message management, a Natural Language Processing (NLP) module, and a backend database. This design ensures an effective, real-time interactive educational platform tailored to improve the learning experience in object-oriented programming.
The architecture begins with Telegram, a popular messaging application, serving as the front-end interface. This layer is crucial as it provides a familiar and accessible point of interaction for users, who can send inputs and receive responses seamlessly. The Telegram API communicates via webhooks, ensuring immediate data transmission to the SnatchBot API, which forms the core of the chatbot's functionality.
SnatchBot manages the session continuity and message routing. This platform is tasked with maintaining the context of user interactions, essential for providing coherent and context-sensitive dialogue, thereby enhancing user engagement and learning efficacy. Its integration facilitates the management of user inputs and system outputs in real time, demonstrating its role in the chatbot's operational framework.

Adjacent to SnatchBot is the NLP module, responsible for processing user inputs. This module performs several functions, entity recognition, and response generation, using algorithms to interpret and process natural language. The ability of the NLP module to accurately understand and respond to user queries is pivotal in simulating a natural and engaging educational interaction. SnatchBot allows the use of a PLN module for the optimization of the ChatBot's responses, which receives a bank of words related to the interactions used by the ChatBot, so that the ChatBot has a better recognition of the user's intentions. A word bank was provided for general topics such as Classes, Polymorphism, Abstract Methods, so on, with the purpose that the ChatBot prioritises these topics.

Supporting these components is a backend database, which stores data pertinent to user interactions, content retrieval, and conversation logs. This database is essential for the NLP module to access historical data and content necessary for generating informed and personalized responses.

The deployment of the bot on Telegram settings the application of these technologies in educational sceneries (see Fig. 4).

Survey results from 87 participants indicated a substantial validation of the ChatBot, with 90% of students reporting satisfaction levels ranging from satisfied to very satisfied, underscoring its potential as an effective pedagogical tool (see Fig 5). In the general satisfaction questions, utility, response speed, and feedback were measured. The ChatBot's design, embodying both an amicable personality and sophisticated computational features, was pivotal in facilitating an engaging and responsive educational experience for the students. These results emphasize not only the overall satisfaction but also specific aspects contributing to the ChatBot's effectiveness in enhancing learning outcomes.

Furthermore, when examining the responses in detail, it became evident that the ChatBot's utility played a significant role in user satisfaction. Students highlighted its ability to provide relevant information promptly, enabling them to grasp complex concepts with ease. Additionally, the ChatBot's swift response speed was recognized as a key factor contributing to its effectiveness, ensuring that students received timely assistance and guidance whenever needed. Moreover, the provision of constructive feedback by the ChatBot was valued by users, as it allowed them to gauge their understanding and progress in real-time, fostering a supportive learning environment.

4.6. Ethical Considerations of Chatbot Implementation

The implementation and use prioritizes ethical considerations to ensure responsible AI application and protect students' rights and privacy. It emphasizes data privacy and security by not collecting or storing personal data, encrypting data sharing, and securing access while ensuring students are aware their data isn't used. Consent and transparency are maintained by informing students about chatbot interactions and obtaining explicit consent before any data collection. Additionally, the potential for AI biases leading to unfair treatment is acknowledged, with students informed about the possibility of such biases in the AI models used.

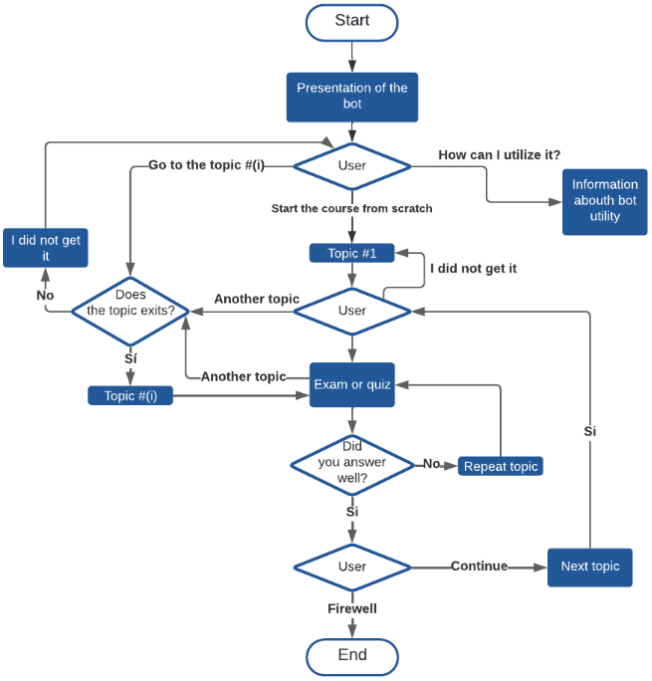

Fig. 2. *Diagram representing the conversational scheme.*
Source: *Authors elaboration.*

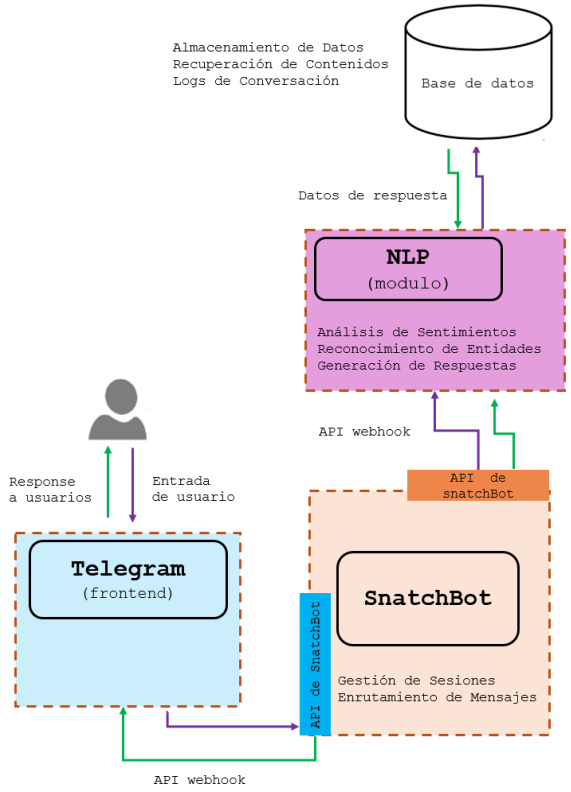

Fig. 3. *Bot's System architecture.*
Source: *Authors elaboration.*

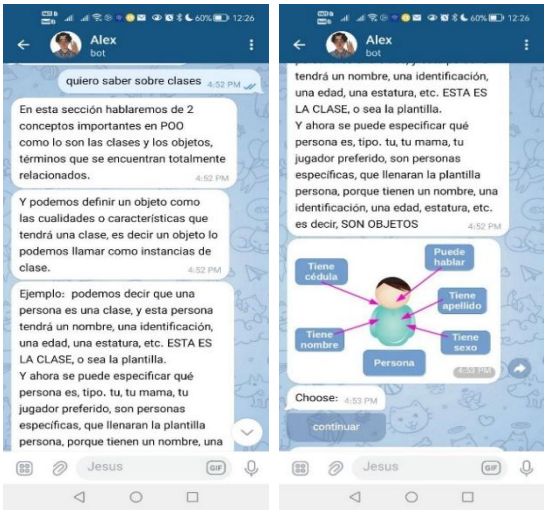

Fig. 4. *Chatbot on Telegram.*
Source: *Authors elaboration.*

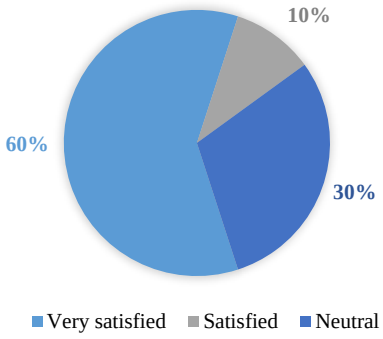

Fig. 5. *User satisfaction about "Profe Alex" explaining.*
Source: *Authors elaboration.*

5. CONCLUSIONS

This study outlines the systematic development of "Profe Alex," a ChatBot designed to support learning in Object-Oriented Programming (OOP) among Systems Engineering students. The methodology involved five critical phases, each contributing uniquely to the bot's educational efficacy and user experience:

- Defining the Bot's Objectives: We established clear educational goals aimed at enhancing the understanding and engagement of students with OOP concepts.
- Characterization of the Bot's Personality: The bot was designed with a friendly and engaging personality to facilitate approachable and effective communication with students.
- Selection of the Development Framework: The choice of SnatchBot and its integration with

Telegram allowed for robust and flexible chatbot functionality, suitable for educational purposes.

- Elaboration of the Conversational Schema: We developed a structured interaction pattern that supports educational content delivery and addresses student queries effectively.
- Implementation: The deployment on Telegram enabled real-time interaction, while continuous feedback and adjustments were made based on user interactions to optimize the learning experience.

Survey results from 87 participants validated the ChatBot's effectiveness, with 90% of students expressing satisfaction levels ranging from satisfied to very satisfied, highlighting its potential as a significant pedagogical tool. The design of the ChatBot, which combined a pleasant personality with advanced computational features, played a crucial role in providing an engaging and responsive educational environment.

The positive reception of the bot, despite the presence of neutral responses, suggests the need for future research to identify improvement opportunities and more effectively tailor the ChatBot to educational needs. This study proposes a contribution in integrating Artificial Intelligence (AI)-based tools within education, demonstrating their potential to enrich traditional teaching methodologies. Future efforts will focus on refining the ChatBot's Natural Language Processing (NLP) capabilities to enhance its applicability and accuracy across different educational contexts. The findings underscore the value of continuing and expanding the use of AI in education, particularly in complex areas such as Object-Oriented Programming (OOP), to improve the quality and access to learning experiences.

REFERENCES

[1] S. M. Lee y D. Lee, «"Untact": a new customer service strategy in the digital age», Service Business, vol. 14, n.o 1, pp. 1-22, 2020.

[2] C. Henríquez, F. Briceño, y D. Salcedo, «Unsupervised Model for Aspect-Based Sentiment Analysis in Spanish», IAENG International Journal of Computer Science, n.o 3, pp. 430-438, 2019.

[3] E. Cambria y B. White, «Jumping NLP curves: A review of natural language processing research», IEEE Computational Intelligence Magazine. 2014. doi: 10.1109/MCI.2014.2307227.

[4] B. A. Shawar y E. Atwell, «Chatbots: are they really useful?», en Ldv forum, 2007, pp. 29-49.

[5] J. Sjostrom y M. Dahlin, «Tutorbot: A Chatbot for Higher Education Practice», en Designing for Digital Transformation. Co-Creating Services with Citizens and Industry: 15th International Conference on Design Science Research in Information Systems and Technology, DESRIST 2020, Kristiansand, Norway, December 2–4, 2020, Proceedings, Berlin, Heidelberg: Springer-Verlag, dic. 2020, pp. 93-98. doi: 10.1007/978-3-030-64823-7_10.

[6] I. V. Serban et al., «A deep reinforcement learning chatbot», arXiv preprint arXiv:1709.02349, 2017.

[7] A. Xu, Z. Liu, Y. Guo, V. Sinha, y R. Akkiraju, «A new chatbot for customer service on social media», en Proceedings of the 2017 CHI conference on human factors in computing systems, 2017, pp. 3506-3510.

[8] T. Okuda y S. Shoda, «AI-based chatbot service for financial industry», Fujitsu Scientific and Technical Journal, vol. 54, n.o 2, pp. 4-8, 2018.

[9] D. C. Ukpabi, B. Aslam, y H. Karjaluoto, «Chatbot adoption in tourism services: A conceptual exploration», en Robots, artificial intelligence, and service automation in travel, tourism and hospitality, Emerald Publishing Limited, 2019.

[10] K. N. Lakshmi, Y. K. Reddy, M. Kireeti, T. Swathi, y M. Ismail, «Design and implementation of student chat bot using AIML and LSA», International Journal of Innovative Technology and Exploring Engineering, vol. 8, n.o 6, pp. 1742-1746, 2019.

[11] P. Smutny y P. Schreiberova, «Chatbots for learning: A review of educational chatbots for the Facebook Messenger», Computers & Education, vol. 151, p. 103862, 2020.

[12] E. Adamopoulou y L. Moussiades, «An overview of chatbot technology», en IFIP International Conference on Artificial Intelligence Applications and Innovations, 2020, pp. 373-383.

[13] C. Henriquez, G. Sánchez-Torres, y D. Salcedo, «Tashi-Bot: A Intelligent Personal Assistant for Users in an Educational Institution», 2021.

[14] Z. H. Krullaars, A. Januardani, L. Zhou, y E. Jonkers, «Exploring Initial Interactions: High School Students and Generative AI Chatbots for Relationship Development», 2023.

[15] A. K. Abdallah, A. M. Alkaabi, D. A. F. Mehiar, y Z. A. J. Aradat, «Chatbots in Classrooms: Tailoring Education and Boosting Engagement», en Cutting-Edge Innovations in

Teaching, Leadership, Technology, and Assessment, IGI Global, 2024, pp. 166-181.

[16] S. Yang y C. Evans, «Opportunities and challenges in using AI chatbots in higher education», en Proceedings of the 2019 3rd International Conference on Education and E-Learning, 2019, pp. 79-83.

[17] N. Sandu y E. Gide, «Adoption of AI-Chatbots to enhance student learning experience in higher education in India», en 2019 18th International Conference on Information Technology Based Higher Education and Training (ITHET), 2019, pp. 1-5.

[18] H. T. Hien, P.-N. Cuong, L. N. H. Nam, H. L. T. K. Nhung, y L. D. Thang, «Intelligent assistants in higher-education environments: the FIT-EBot, a chatbot for administrative and learning support», en Proceedings of the ninth international symposium on information and communication technology, 2018, pp. 69-76.

[19] C. Henriquez, D. Salcedo, y A. Cortés-Cabezas, «Development of a Chatbot as an Intelligent Personal Assistant for Teaching and Learning Data Structures», Prospectiva, vol. 22, n.o 1, 2024.

[20] C. W. C y A. Ade-Ibijola, «Python-Bot: A Chatbot for Teaching Python Programming».

[21] O. A. Cadena y I. A. Juárez, «La enseñanza de la programación mediante software educativo especializado y los agentes conversacionales», Interfases, n.o 017, pp. e6337-e6337, 2023.

[22] J. E. S. García, M. U. Ruiz, y B. E. G. Herrera, «Análisis de los problemas de aprendizaje de la programación orientada a objetos», Ra Ximhai: revista científica de sociedad, cultura y desarrollo sostenible, vol. 11, n.o 4, pp. 289-304, 2015.

[23] L. Labadze, M. Grigolia, y L. Machaidze, «Role of AI chatbots in education: systematic literature review», International Journal of Educational Technology in Higher Education, vol. 20, n.o 1, p. 56, oct. 2023, doi: 10.1186/s41239-023-00426-1.

[24] M. A. Kuhail, N. Alturki, S. Alramlawi, y K. Alhejori, «Interacting with educational chatbots: A systematic review», Education and Information Technologies, vol. 28, n.o 1, pp. 973-1018, jul. 2022, doi: 10.1007/s10639-022-11177-3.

[25] O. Chinedu y A. Ade-Ibijola, «Python-Bot: A Chatbot for Teaching Python Programming», Engineering Letters, vol. 29, pp. 25-34, feb. 2021.

[26] H. B. Essel, D. Vlachopoulos, A. Tachie-Menson, E. E. Johnson, y P. K. Baah, «The impact of a virtual teaching assistant (chatbot) on students' learning in Ghanaian higher education», International Journal of Educational Technology in Higher Education, vol. 19, n.o 1, p. 57, nov. 2022, doi: 10.1186/s41239-022-00362-6.

[27] S. I. Malik, M. W. Ashfque, R. M. Tawafak, G. Al-Farsi, N. Ahmad Usmani, y B. Hamza Khudayer, «A Chatbot to Facilitate Student Learning in a Programming 1 Course: A Gendered Analysis», International Journal of Virtual and Personal Learning Environments (IJVPLE), vol. 12, n.o 1, pp. 1-20, 2022, doi: 10.4018/IJVPLE.310007.

[28] D. Ramandanis y S. Xinogalos, «Designing a Chatbot for Contemporary Education: A Systematic Literature Review», Information, vol. 14, n.o 9, Art. n.o 9, sep. 2023, doi: 10.3390/info14090503.

[29] T. Kosar, D. Ostojić, Y. D. Liu, y M. Mernik, «Computer Science Education in ChatGPT Era: Experiences from an Experiment in a Programming Course for Novice Programmers», Mathematics, vol. 12, n.o 5, Art. n.o 5, ene. 2024, doi: 10.3390/math12050629.

[30] J. Yin, T.-T. Goh, B. Yang, y Y. Xiaobin, «Conversation Technology With Micro-Learning: The Impact of Chatbot-Based Learning on Students' Learning Motivation and Performance», Journal of Educational Computing Research, vol. 59, n.o 1, pp. 154-177, mar. 2021, doi: 10.1177/0735633120952067.

[31] X. Deng y Z. Yu, «A Meta-Analysis and Systematic Review of the Effect of Chatbot Technology Use in Sustainable Education», Sustainability, vol. 15, n.o 4, Art. n.o 4, ene. 2023, doi: 10.3390/su15042940.

[32] Z. Bahroun, C. Anane, V. Ahmed, y A. Zacca, «Transforming Education: A Comprehensive Review of Generative Artificial Intelligence in Educational Settings through Bibliometric and Content Analysis.», Sustainability, vol. 15, n.o 17, p. NA-NA, ago. 2023.

[33] D. H. Chang, M. P.-C. Lin, S. Hajian, y Q. Q. Wang, «Educational Design Principles of Using AI Chatbot That Supports Self-Regulated Learning in Education: Goal Setting, Feedback, and Personalization», Sustainability, vol. 15, n.o 17, Art. n.o 17, ene. 2023, doi: 10.3390/su151712921.

[34] F. H. Wang, «Efficient generation of text feedback in object-oriented programming education using cached performer revision», Machine Learning with Applications, vol. 13,

p. 100481, sep. 2023, doi: 10.1016/j.mlwa.2023.100481.

[35] F. H. Wang, «A Feasible Study of a Deep Learning Model Supporting Human–Machine Collaborative Learning of Object-Oriented Programming», IEEE Transactions on Learning Technologies, vol. 17, pp. 413-427, 2024, doi: 10.1109/TLT.2022.3226345.