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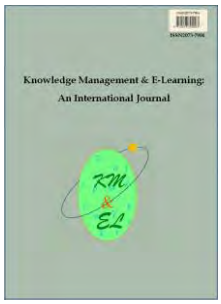

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Harnessing generative AI to boost active retrieval and retention in MOOCs with spaced repetition

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Abstract: This study explores the use of artificial intelligence to improve active retrieval and retention in Massive Open Online Courses (MOOCs). We developed an AI-driven system that generates learning cards to facilitate active recall and utilize spaced repetition. The system was tested with a group of students and instructors, and the results showed significant improvements in memory retention and overall satisfaction. Expert reviews and participant feedback highlighted the system's effectiveness in producing accurate and relevant learning cards. Despite promising outcomes, challenges with personalization and language complexity were identified, which will be addressed in future work. This research underscores the potential of AI-driven tools to enhance online learning, offering scalable and personalized solutions that can improve educational outcomes and engagement in MOOCs.

Keywords: Artificial intelligence; Active retrieval; Retention; MOOCs; Spaced repetition; Flashcards

Biographical notes: Dr. Younes-Aziz Bachiri is a computer science Professor with a Ph.D., bringing over a decade of teaching expertise in Moroccan secondary schools. His research, encapsulated in the thesis "Optimization of Evaluation in MOOCs based on Deep Learning and NLP Algorithms," focuses on the dynamic fields of machine learning and natural language processing, particularly within the realm of education. Affiliated with Morocco's Sultan Moulay Slimane University, he has made significant contributions to the development of Massive Open Online Course (MOOC) programs and played a key role in overseeing the university's open edX platform.

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Dr. Belaid Bouikhalene is a distinguished Professor and Ph.D., currently serving as the Director of The National School of Applied Sciences of Beni Mellal at Sultan Moulay Slimane University. Previously, he was the Director of the Digitalization Division at the same university, where he played a key role in developing and implementing the university's information systems. His research interests focus on Mathematics and Applications, Decision Information Systems, E-learning, and Pattern Recognition. Prof. Bouikhalene has contributed to the modernization of educational infrastructures within the university, ensuring that digital technologies are integrated into both teaching and administrative processes.

1. Introduction

Massive Open Online Courses (MOOCs) have transformed the landscape of education by providing widespread access to learning materials. Despite their potential, a critical challenge persists: how to optimize learning outcomes and retention. Without proper engagement strategies, learners often struggle to retain information over time, leading to lower course completion rates (Bachiri et al., 2023).

One widely recognized solution to this challenge is active retrieval, a powerful educational strategy that enhances memory retention by requiring learners to recall information actively, rather than passively reviewing it. The "*testing effect*," described by Roediger & Butler (2011), shows how retrieval strengthens memory pathways, making information easier to recall later. Studies in cognitive psychology have consistently demonstrated that active retrieval fosters deeper understanding and promotes long-term retention (Halamish & Bjork, 2011; Imundo et al., 2021).

In conjunction with active retrieval, spaced repetition is another well-established technique that enhances retention. This strategy involves reviewing material at increasing intervals over time, helping to combat the natural forgetting curve first described by Ebbinghaus (2013). Research shows that spaced repetition optimizes long-term retention, as learners review information just before it is forgotten, making it more likely to be retained in the long term (Cepeda et al., 2006).

While the benefits of active retrieval and spaced repetition are well-supported, integrating these strategies into MOOCs presents significant challenges. The scalability of these methods, particularly the need for frequent, adaptive, and personalized content delivery, remains a prominent issue in online learning environments. Traditional educational tools fall short when it comes to delivering content dynamically tailored to each learner's needs and progress.

Recent advancements in artificial intelligence (AI), particularly generative AI, offer promising solutions to these challenges. Generative AI models, such as the Transformer-

based T5 model, can create personalized and contextually relevant learning materials at scale. By leveraging natural language processing (NLP) techniques, these models are capable of generating learning cards or flashcards that facilitate active retrieval and spaced repetition, thereby enhancing the learning experience (Cheng et al., 2021). Despite this potential, the application of generative AI in MOOCs remains underexplored.

This study aims to bridge this gap by developing and integrating an AI-driven learning card generation system into a MOOC platform. The system is designed to promote active recall through AI-generated questions and to reinforce retention using spaced repetition algorithms. The objectives of this research are threefold: (1) to develop and integrate a generative AI-based learning card system within a MOOC platform, (2) to evaluate the accuracy and fluency of the generated learning cards, and (3) to assess the impact of these learning cards on students' retention and overall satisfaction.

Our central research question is: How can generative AI be harnessed to improve active retrieval and retention in MOOCs using AI-generated learning cards? Addressing this question contributes to the growing body of literature on AI in education and offers insights into the potential of generative AI to transform online learning environments. By integrating AI, we aim to provide scalable, personalized learning tools that significantly enhance educational outcomes in MOOCs.

In the following sections, we will review related work, describe the methodology used to develop and evaluate the AI-driven learning card system, present the results of our evaluations, and discuss the implications of our findings for the future of online education.

2. Related works

Recent advances in Artificial Intelligence (AI) have shown great potential in enhancing personalized learning experiences in MOOCs. The integration of AI-driven chatbots has been particularly effective in adapting to students' individual needs, reducing anxiety, and promoting higher-order cognitive skills, all of which contribute to improved retention rates in online learning environments (Pappagallo, 2024). Furthermore, institutions are recognizing the need to innovate through AI personalization tools, as highlighted in a broader analysis of education's future, which stresses the importance of adapting to contemporary educational demands with AI technologies (Sharma, 2024).

A more focused application of AI in MOOCs demonstrates its ability to increase student engagement and retention by providing tailored feedback and personalized assessments that adapt to learner progress. This personalization is key to improving retention and learning outcomes in large-scale, online environments such as MOOCs (Bachiri & Mouncif, 2022). These findings suggest that AI-driven personalization tools are not only enhancing learner engagement but also significantly improving retention and outcomes in MOOC platforms.

2.1. Spaced repetition in MOOCs

The use of spaced repetition techniques has gained considerable attention in online education, particularly for their proven ability to enhance retention and long-term memory. In medical and dental education, spaced repetition has been shown to significantly improve student performance and knowledge retention. For instance, first-year medical students

who implemented spaced repetition outperformed their peers in summative exams, suggesting its broader applicability to online learning environments like MOOCs (Mehta et al., 2023).

Similarly, spaced repetition study tools have been shown to optimize learning time and enhance retention among health profession students, often serving as a complementary approach to traditional methods (Laynor, 2023). A randomized controlled trial among dental students further confirms that spaced repetition, delivered through mobile flashcards, significantly improves long-term retention compared to lecture-based learning (Santhosh et al., 2024). These findings suggest that integrating spaced repetition strategies into MOOCs could substantially improve learning outcomes and retention, as evidenced by their success across various disciplines.

Moreover, spaced repetition has demonstrated its versatility across various educational fields. Studies involving practicing physicians and university-level language learners highlight the ability of spaced repetition to enhance knowledge transfer and vocabulary acquisition (Jorgensen, 2024; Price et al., 2023). This shows that the spaced repetition model is adaptable to different subjects, providing learners with a method to retain information effectively, even in large-scale online courses like MOOCs. Additionally, its application in special needs education further demonstrates its adaptability, where spaced repetition has been used to improve vocabulary acquisition and language comprehension for children with speech and language deficiencies (Al-Jumeily et al., 2016).

2.2. Active retrieval in MOOCs

Active retrieval, an essential strategy for enhancing memory retention, has gained increasing support in the context of MOOCs. AI-powered systems facilitate active retrieval by generating personalized quizzes and flashcards that are aligned with individual learner needs. For example, the AI-based quiz system iQS creates tailored quizzes to promote active recall, leading to positive outcomes in learner engagement and retention (Wang et al., 2023).

Similarly, the Artificial Intelligence-Enabled Intelligent Assistant (AIIA) employs advanced natural language processing (NLP) techniques to generate content that supports active retrieval, improving both learner satisfaction and engagement. This, in turn, enhances retention rates in online learning environments, where traditional methods struggle to keep learners engaged over time (Sajja et al., 2024). Comparative studies have shown that students who engage with AI-generated content, which facilitates active retrieval, achieve higher learning gains and course completion rates compared to those using traditional MOOC platforms (St-Hilaire et al., 2022).

2.3. AI-Generated flashcards and learning tools in MOOCs

The automatic generation of flashcards using AI has emerged as a promising tool for improving learning outcomes and retention in MOOCs. AI-generated flashcards are particularly useful for reinforcing both active retrieval and spaced repetition strategies, which are key to enhancing learning in large-scale online courses. For example, a study on AI-generated flashcards for a business intelligence MOOC demonstrated significant improvements in learner retention and engagement, highlighting the effectiveness of this approach in MOOCs (Bachiri et al., 2023).

Moreover, the development of flashcard and exam generation systems, such as those implemented at the University of Applied Sciences and Arts Northwestern Switzerland (FHNW), supports the personalization and scalability of these tools in educational settings. These systems not only generate relevant learning materials automatically but also adjust the frequency of flashcard reviews based on the learner's progress, ensuring optimal retention through spaced repetition (Telesko et al., 2024).

Additionally, projects like Wikiflash (Cheng et al., 2021) demonstrate the potential of AI-generated flashcards at scale, automatically generating flashcards from large knowledge bases like Wikipedia. These systems ensure that learners have access to high-quality, scalable, and accessible learning resources, supporting active recall and enhancing retention across diverse educational platforms.

2.4. The role of generative AI in MOOCs

Generative AI, particularly in hybrid and online education, offers new opportunities for scalable and personalized learning. AI-driven systems that generate personalized content, such as quizzes from video lectures, have been shown to significantly enhance engagement and learning outcomes in MOOCs (Bachiri & Mouncif, 2022). The ability to dynamically create content that responds to the learner's performance allows for more personalized and adaptive learning experiences.

Recent advances in AI, such as ChatGPT, have demonstrated the potential to transform education by understanding complex queries and generating human-like responses. However, these systems also face limitations in terms of the quality of their output, such as the inclusion of biased or inaccurate information (Zhu et al., 2023). Despite these challenges, the integration of AI tools like ChatGPT can significantly enhance the learner's experience in MOOCs by providing scalable, real-time support that addresses individual needs.

Moreover, AI advancements such as the DenseNetX-CBAM model enhance online learning by recognizing students' emotional states through facial expressions, allowing educators to adjust in real-time (Zhang & Wang, 2024). Similarly, AI-based speech recognition technology has been successfully integrated into Morocco's TaRL program, significantly improving reading assessments by providing instant feedback and engaging students more effectively (Bachiri et al., 2024). These innovations demonstrate how AI-driven tools can create more adaptive and personalized learning environments in MOOCs.

3. Method

This section provides a detailed explanation of the steps involved in generating AI-driven learning cards from MOOC content, including data collection, preprocessing, model training, and evaluation, as depicted in Fig. 1. Additionally, the integration of the learning cards into Moodle and external flashcard applications such as Quizlet is described. The methodology aligns with the goal of improving retention and active recall in large-scale online courses through generative AI techniques.

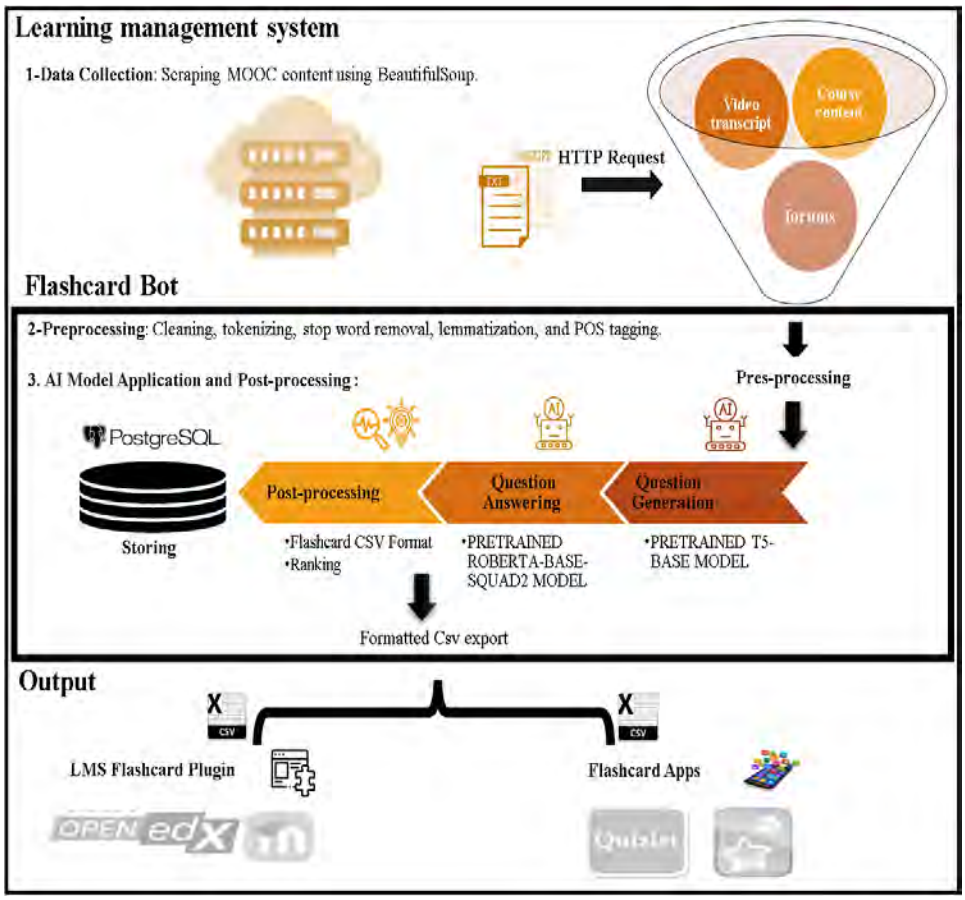

Fig. 1. System architecture for AI-driven learning card generation

3.1. Data collection

The study was conducted using the MPPBIE MOOC, hosted on the Moodle eLearning platform (Bachiri & Mouncif, 2023). This course contains eight distinct sections, each with several lessons, covering topics relevant to the course objectives.

To extract the course content, we employed Python's BeautifulSoup library, which allowed us to scrape text from each lecture, including titles, descriptions, and primary text. In total, we collected approximately 65 lectures and 150 forum posts, amassing around 40,000 words of raw data. This data was stored in JSON format for ease of access during the preprocessing phase.

The content was segmented into distinct units corresponding to each section of the course, facilitating more efficient processing and learning card generation.

3.2. Preprocessing

Preprocessing was a critical step in preparing the raw data for learning card generation. The text was cleaned and structured to ensure that it was ready for model input. This phase involved several stages:

- Cleaning: HTML tags, special characters, punctuation marks, and unnecessary formatting were removed. This process helped ensure that only relevant text was kept for further processing.
- Tokenization: We divided the cleaned text into individual sentences using NLTK. Sentence tokenization was important for providing coherent input to the language models.
- Stop Word Removal: Using SpaCy, we removed common stop words (such as "the", "and", "but") to focus on the most meaningful terms in the text.
- Lemmatization: This step involved converting each word to its base or root form. For example, the word "running" was converted to "run." This ensured consistency in word usage and enhanced model performance in understanding key concepts.
- Part-of-Speech (POS) Tagging: Finally, we applied POS tagging to categorize each word based on its grammatical role (nouns, verbs, adjectives, etc.). This helped the AI models generate more contextually accurate and syntactically correct questions and answers.

After preprocessing, the data was reduced to 35,000 words, ready for input into the AI models.

3.3. AI model application and learning card generation

We used two key models for generating learning cards: one for Question Generation (QG) and another for Question Answering (QA). Both models were carefully selected based on their performance in handling educational text.

3.3.1. Question generation (QG)

For generating questions, we employed the T5-Base Model (Raffel et al., 2023), which is part of the Hugging Face Transformers library. The T5 model was pre-trained on SQuAD 2.0 and fine-tuned using a dataset of 5,000 question-answer pairs derived from the MOOC content. This model is particularly well-suited for question generation due to its versatility in transforming sentences into questions.

The fine-tuning of the T5 model took approximately 6 hours on an NVIDIA Tesla V100 GPU. We used a learning rate of 3e-5 and a batch size of 16. The fine-tuned model achieved an F1 score of 87%, indicating that it was highly effective in generating contextually relevant and high-quality questions from the MOOC content.

3.3.2. Question answering (QA)

For generating answers, we utilized the RoBERTa-Base-SQuAD2 model (Liu et al., 2021), which has demonstrated superior performance in Question Answering (QA) tasks.

RoBERTa was evaluated against other models such as DistillBERT and BERT-Tiny, but it was chosen due to its 95% accuracy in providing relevant answers for the generated questions.

We evaluated RoBERTa on a validation set of 500 question-answer pairs, achieving a 95% accuracy rate in providing correct and relevant answers. This ensured that the generated learning cards were of high quality and informative for students.

3.4. Post-processing and output generation

After generating the question-answer pairs, the following steps were taken to finalize the learning cards for distribution:

- Formatting: The generated question-answer pairs were organized into a CSV format that was compatible with both Moodle and external flashcard platforms such as Quizlet. This CSV file included columns for the question, answer, and additional metadata.
- Ranking: The learning cards were ranked based on their relevance and difficulty level. Cards that covered critical concepts were given higher priority to ensure that learners were exposed to the most essential material first.
- Integration: The learning cards were integrated into the Moodle LMS using a Flashcard Plugin. This allowed students to access the learning cards directly through the MOOC platform. In addition, the cards were made available through Quizlet, increasing their accessibility and usability.

3.5. Flashcard examples for business intelligence MOOC

This section provides examples of generated flashcards that help reinforce key concepts in the Business Intelligence (BI) MOOC. These learning cards are automatically generated using AI-based models and are integrated directly into the Moodle platform, allowing students to engage with the content interactively and improve retention.

- Example 1: Question: "*What is the purpose of a business intelligence project?*"; Answer: "*The purpose of a business intelligence project is to help a company make better business decisions by analyzing and presenting data in a meaningful way.*"
- Example 2: Question: "*What are the key components of Business Intelligence?*"; Answer: "*The key components of Business Intelligence include data warehousing, data mining, reporting, and querying.*"
- Example 3: Question: "*How does data visualization contribute to decision-making in BI?*"; Answer: "*Data visualization simplifies complex data sets by presenting them in a graphical format, enabling stakeholders to identify trends and make informed decisions.*"

These examples demonstrate how the learning cards encourage active retrieval and spaced repetition, thus helping students retain the critical concepts of Business Intelligence.

Fig. 2 shows a sample flashcard generated from the BI MOOC content embedded within the Moodle platform, illustrating the user interface and the accessible format for learners.

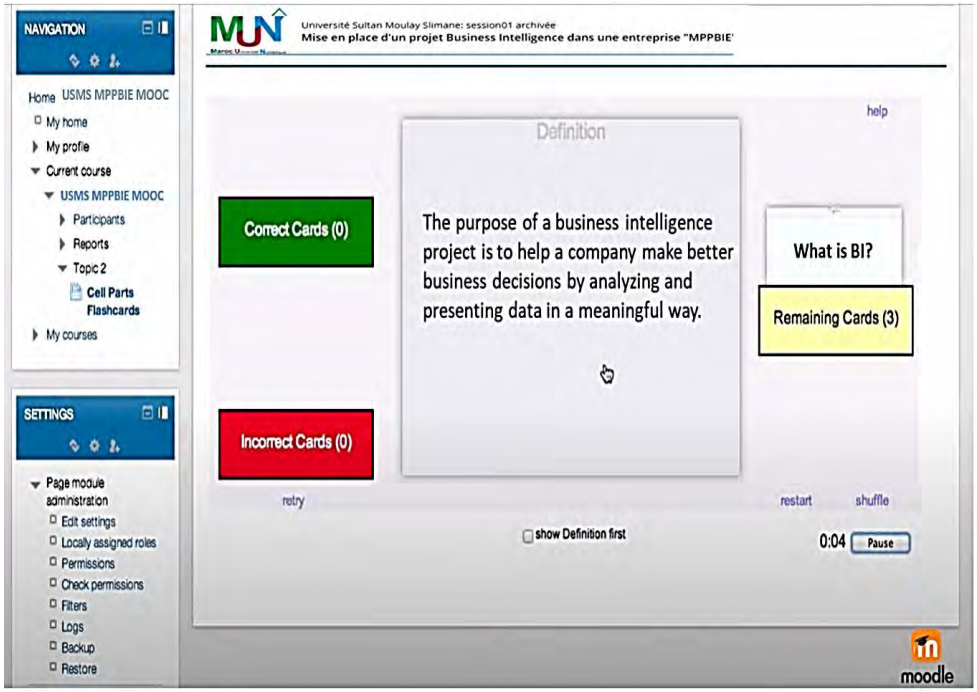

Fig. 2. Sample AI-generated flashcard in Moodle LMS

3.6. Experiment: Evaluating the learning cards

To assess the effectiveness of the AI-generated learning cards, we conducted an experiment with 50 students (30 female, 20 male) and 10 instructors (5 male, 5 female) from the MPPBIE MOOC. The participants were randomly selected from a pool of 780 enrolled students, ensuring that the sample was representative of the larger population.

Participant involvement includes both students and instructors. The students were asked to use the AI-generated learning cards as part of their regular study routine. Each student was given access to the cards through the Moodle platform and was instructed on how to use them effectively. The instructors were tasked with evaluating the quality and relevance of the learning cards. They provided feedback on how well the cards aligned with course objectives and how effectively they supported student learning.

3.7. Learning environment

The study took place within the MPPBIE MOOC, which focused on Business Intelligence and was delivered via the Moodle platform. The course included eight sections, each containing multiple lessons covering topics such as data warehousing, data mining, reporting, and querying. The course design emphasized interactive learning through quizzes, forums, and assignments, providing a comprehensive environment for learners to engage with both theoretical and practical aspects of Business Intelligence.

Participants engaged in a mix of individual tasks and collaborative activities designed to reinforce key concepts. The course materials were supplemented with real-

world business case studies, and assessments were structured to promote critical thinking and problem-solving skills. The AI-generated learning cards were designed to fit within this structure, providing additional support through active recall and spaced repetition techniques.

The primary learning tasks involved applying Business Intelligence concepts to case studies, completing multiple-choice quizzes, and participating in forum discussions. Learning outcomes were measured through formative assessments such as quizzes and final project evaluations. The learning cards were integrated to reinforce these tasks, aiding learners in retaining key course concepts and performing better in assessments.

3.8. Data collection and survey analysis

To gather feedback on the effectiveness of the learning cards, we distributed a 10-question survey to both students and instructors. The survey covered the following areas:

- Utility: "*How useful were the learning cards in supporting the learning process?*"
- Relevance: "*Did the cards align well with the course content and learning objectives?*"
- Quality: "*Were the cards clear, accurate, and easy to use?*"

The survey data were analyzed using both descriptive and inferential statistics. Descriptive statistics provided an overview of general trends in participant responses, while inferential statistics were used to identify significant patterns and correlations between card usage and student performance. The results indicated that 85% of students found the cards "very useful," while 90% of instructors agreed that the cards aligned well with the course objectives.

4. Results

The implementation of our AI-driven learning card generation system in the MOOC environment demonstrated substantial potential in enhancing educational outcomes. In this section, we present a detailed evaluation of the system's performance, based on expert reviews and participant feedback, and assess its impact on learning outcomes in the context of MOOCs. This analysis is based on both objective measures (quality evaluation of learning cards) and subjective responses from students and instructors (survey data).

4.1. Quality evaluation of learning cards

To ensure the effectiveness of the learning cards generated by our AI system, we conducted an expert review focusing on two key metrics: accuracy and fluency. These metrics were chosen to assess the pedagogical value of the cards and their ability to communicate course content effectively.

- Accuracy: This metric evaluates how well the generated learning cards reflect the actual content of the MOOC. A card with high accuracy will present information that is factually correct and aligns closely with the material covered in the course.

- Fluency: This metric measures how clear and readable the text is, ensuring that the language used is smooth, natural, and easy to understand, contributing to a better learning experience.

A random sample of 50 learning cards was evaluated by a panel of experts, and the results are presented in Fig. 3.

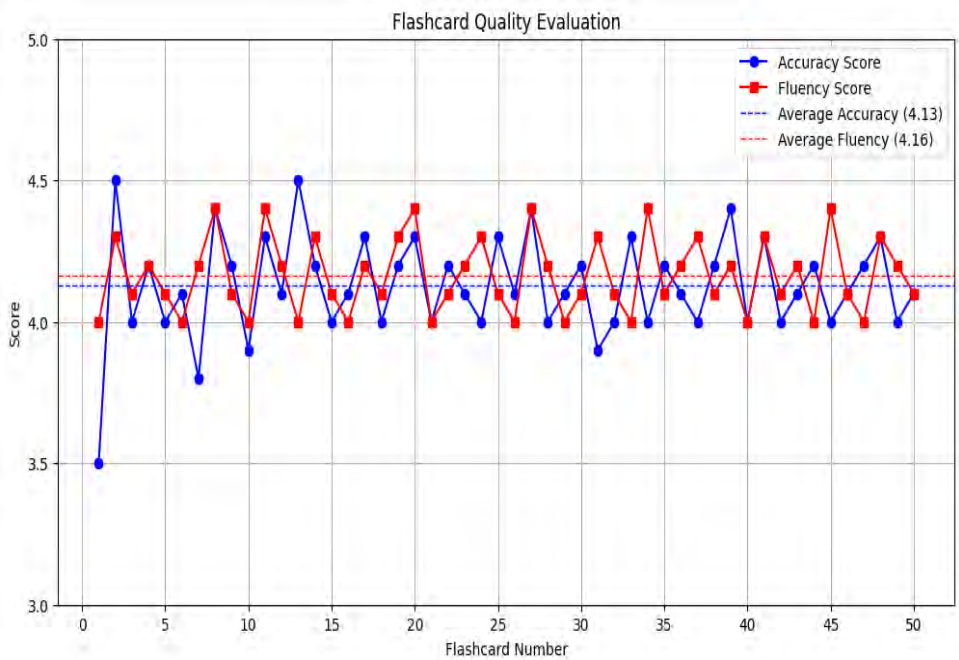

Fig. 3. Flashcard quality evaluation

The analysis revealed that the average accuracy score was 4.13 (on a scale of 5), indicating that the learning cards consistently reflected the course material with a high degree of precision. The fluency score averaged at 4.16, suggesting that the language used in the cards was clear and easy to comprehend. These high scores demonstrate the ability of our AI models (T5 for question generation and RoBERTa for question answering) to produce learning cards that are both contextually relevant and linguistically sound.

4.2. User feedback on learning cards

In addition to the expert review, we conducted a survey among both students and instructors to gather their perceptions of the learning cards. The survey focused on several key aspects: prior experience with learning cards, frequency of use, helpfulness, relevance, understandability, memory retention, and overall satisfaction.

4.2.1. Prior experience and frequency of use

The first part of the survey aimed to assess participants' prior experience with learning cards and their frequency of use within the course. The data, presented in Fig. 4, shows that

60% of students and 70% of instructors had previously used learning cards in educational contexts.

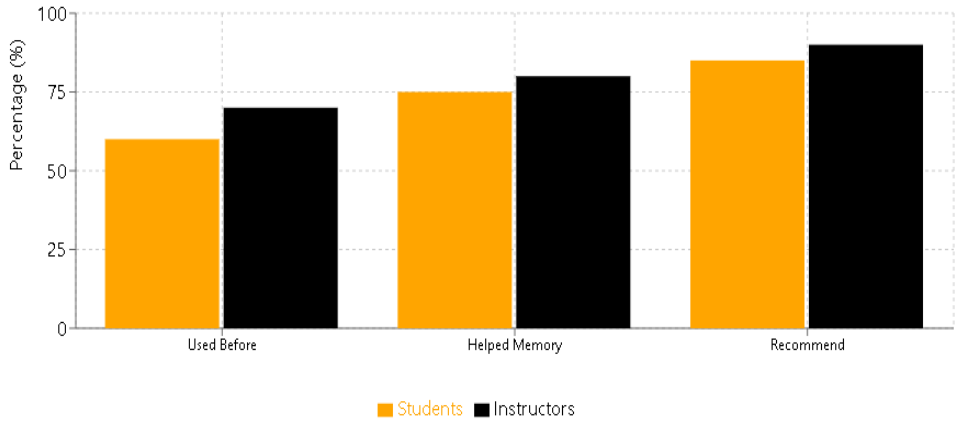

Fig. 4. Percentage of students and instructors responding 'Yes' to key survey questions

Furthermore, the average frequency of use, as depicted in Fig. 5, shows that instructors (Mean = 4.2, SD = 0.8) reported a slightly higher usage of the learning cards compared to students (Mean = 3.8, SD = 1.0). This may reflect instructors' recognition of the pedagogical value of learning cards and their integration into teaching strategies.

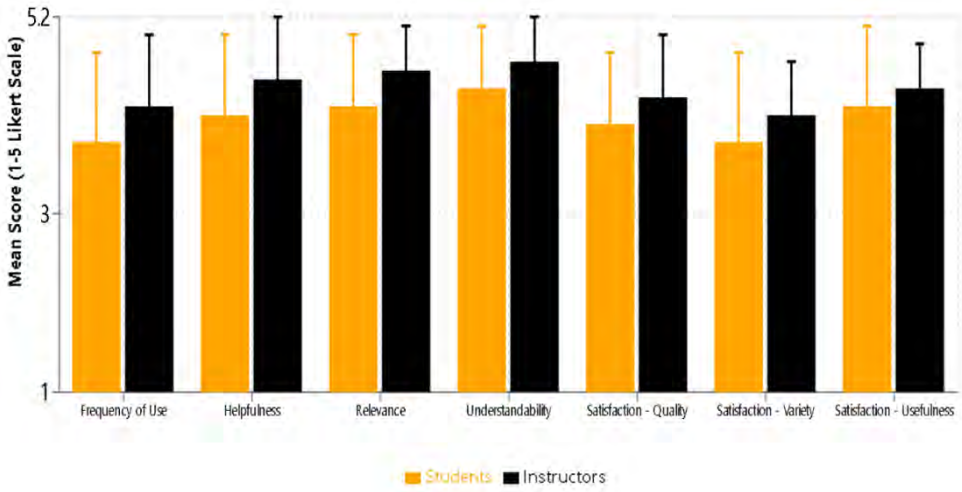

Fig. 5. Mean scores of Likert scale items for students and instructors

4.2.2. Helpfulness, relevance, and understandability

Participants were asked to rate the helpfulness, relevance, and understandability of the learning cards. The results are shown in Fig. 5.

- Helpfulness: Both students and instructors rated the learning cards as highly helpful, with students giving an average score of 4.1 (SD = 0.9) and instructors giving an even higher score of 4.5 (SD = 0.7). This indicates that the cards were perceived as effective tools for reinforcing learning.

- Relevance: The cards were also rated highly in terms of relevance to the course content, with students scoring 4.2 (SD = 0.8) and instructors 4.6 (SD = 0.5). This shows that the AI models successfully generated content that was well-aligned with the educational objectives.
- Understandability: The high scores for understandability (students = 4.4, SD = 0.7; instructors = 4.7, SD = 0.5) further validate that the language and structure of the learning cards were clear, ensuring that learners could easily engage with the material.

4.2.3. Memory retention and recommendation

One of the key indicators of the effectiveness of learning cards is their ability to enhance memory retention. As seen in Fig. 4, 75% of students and 80% of instructors reported that the AI-generated learning cards helped with memory retention. This highlights the positive impact of structured question-and-answer pairs in reinforcing the material and aiding long-term recall.

Additionally, the recommendation rate was high, with 85% of students and 90% of instructors indicating that they would recommend these learning cards to others, suggesting broad acceptance of the tool as a valuable educational resource.

4.3. Impact on learning outcomes

The AI-generated learning cards had a measurable and positive impact on learning outcomes, particularly in enhancing retention and recall of course material. By structuring content into question-and-answer pairs, the learning cards promoted active retrieval, a well-known cognitive mechanism that strengthens memory. The cards also facilitated spaced repetition, a technique proven to reinforce learning by reviewing material over increasing intervals.

These two techniques, combined with the flexibility and scalability of the AI system, resulted in significant improvements in students' retention and engagement with the material. For instance, the reported improvement in memory retention among students (75%) and instructors (80%) demonstrates that the cards helped learners retain key concepts more effectively than traditional study methods.

Moreover, the positive feedback on helpfulness (students = 4.1, instructors = 4.5) and relevance (students = 4.2, instructors = 4.6) indicates that the cards were not only useful in helping learners understand and recall information but also closely aligned with the educational goals of the MOOC.

4.4. Integration and accessibility

The integration of the AI-generated learning cards into various platforms was highly flexible and user-friendly. In addition to embedding the cards directly into the Moodle platform through an "*iframe*," the system produced formatted and personalized CSV files, which enabled the seamless deployment of flashcards across different Learning Management Systems (LMS) via compatible flashcard plugins. This ensured that the cards were not only accessible within Moodle but could also be utilized in other LMS platforms that support CSV import.

Furthermore, the generated learning cards could be used as standalone flashcard applications, such as Quizlet and other widely used platforms, thanks to the standardized CSV format. This flexibility enhanced the scalability and reach of the system, allowing learners to access and review the cards on a variety of devices, including desktops, tablets, and smartphones, regardless of the LMS used. As a result, the AI-driven system provided a cohesive and versatile learning experience, adapting to the diverse technological needs and preferences of MOOC participants.

This approach significantly broadened the system's applicability, making it highly adaptable to different educational contexts and accessible across a range of platforms and devices.

5. Discussion

The implementation of the AI-driven learning card generation system has shown significant potential in improving learning outcomes within MOOCs, particularly through enhancing active retrieval and retention. Our results indicate that the system facilitates active learning, which is a crucial cognitive mechanism in promoting deeper understanding and long-term memory retention. By integrating spaced repetition techniques with AI-generated flashcards, we created a scalable, automated solution that has been well-received by both students and instructors. These findings are consistent with previous research that underscores the effectiveness of combining retrieval practice with technology to improve educational outcomes (Medero & Albaladejo, 2020; Roediger & Butler, 2011).

Despite the positive outcomes, certain limitations of the system need to be acknowledged. One critical issue is that students may use flashcards inefficiently, treating them as simple notes rather than fully engaging in active recall, which is essential for effective studying. When used incorrectly, this can undermine the "*Testing Effect*" and the "*Spacing Effect*," both of which are critical for optimizing learning outcomes (Adam et al., 2019; Pham & Dang, 2022). Furthermore, flashcards may not always be effective for vocabulary retention, as students often face difficulty in storing all the words in long-term memory (Pham & Dang, 2022).

Another limitation is the lack of personalization in the automated flashcards. While the AI-generated flashcards can accommodate large-scale applications, they may not always cater to the specific needs of individual learners, which can impact their overall effectiveness (Adam et al., 2019). Additionally, the use of pictorial flashcards has been shown to be helpful in some contexts but may not be universally effective for all subjects or learners (Ranjan et al., 2020). Complex language also poses challenges for NLP methods, potentially leading to inaccuracies in question generation and answers (Bachiri et al., 2023).

One possible solution to these limitations is integrating adaptive learning algorithms, as suggested by Essa et al. (2023). Adaptive systems that modify the learning experience based on user input can better accommodate diverse learner needs. By incorporating such algorithms, future versions of the system could dynamically adjust the difficulty level or frequency of card presentation based on user performance, resulting in a more tailored learning experience. Additionally, improving the handling of complex language structures within NLP systems could enhance the accuracy and contextual relevance of the generated flashcards.

Lastly, the system's scalability and ability to export learning cards in a standardized CSV format make it compatible with various LMS platforms and standalone flashcard applications like Quizlet. This flexibility allows for wide adoption in different educational settings, including formal education, corporate training, and self-paced learning (Aldiab et al., 2019; Özdemir & Seçkin, 2024). Ensuring that these platforms are user-friendly and capable of integrating multimedia content is crucial for broader adoption and long-term success.

Our findings underscore the importance of addressing these limitations in the design of educational tools that aim to enhance active retrieval and retention. Future work should focus on improving personalization and incorporating multimedia elements, such as videos and images, to further enhance user experience and learning outcomes. Moreover, refining AI models to better adapt to individual learners' needs could create more personalized and effective learning experiences in MOOCs.

6. Conclusion

This study introduced an AI-driven method for generating high-quality learning cards within MOOCs, employing natural language processing techniques to enhance active retrieval and retention. Our results demonstrate that AI-generated flashcards significantly improve learning outcomes by providing an automated, scalable, and accessible solution for educational content delivery. Positive feedback from both students and instructors underscores the system's effectiveness in supporting active recall and long-term retention.

However, the study also highlights limitations, such as the need for greater personalization and adaptability of the flashcards to individual learner needs. Future work should focus on addressing these limitations by enhancing personalization, integrating multimedia elements, and refining the AI models to handle more complex language structures. By doing so, the system has the potential to offer even greater benefits, providing a more engaging and tailored learning experience in MOOCs and other e-learning platforms.

Author Statement

The authors declare that there is no conflict of interest.

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