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Human-Algorithm Collaboration: The Future of Decision-Making in Personalized Learning Systems

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Abstract:
This study aims to analyze the collaboration between humans and algorithms in decision-making in personalized learning systems. This collaboration is a new paradigm in modern education, demanding a balance between artificial intelligence and human wisdom. The research method used is descriptive-qualitative with a phenomenological approach to understand how teachers interact with algorithmic systems in determining learning strategies. The results show three main findings. First, the emergence of a hybrid decision-making model that integrates the analytical capabilities of algorithms with teachers' contextual interpretations, resulting in more adaptive and personalized learning decisions. Second, there is a transformation in the role of teachers from mere evaluators to digital curators who play an active role in analyzing data, designing learning experiences, and providing evidence-based feedback. Third, the integration of ethical values is a crucial controlling factor so that algorithmic systems remain aligned with the principles of justice, empathy, and humanity. These findings strengthen the theory of human–AI collaboration and the ethics of educational technology, which emphasize that technology cannot completely replace human moral intuition. This research contributes to the development of a future learning framework that positions artificial intelligence as a reflective partner for educators in creating intelligent, equitable, and humanity-oriented learning.

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human–algorithm collaboration, decision making, personalized learning, educational ethics, transformation of teacher roles.

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INTRODUCTION

The development of artificial intelligence (AI) technology has brought fundamental changes to the world of education. Learning systems that were once uniform are now shifting toward a personalized, data-driven approach, where each student's needs, learning style, and abilities can be identified more precisely(Muslim Mubarok et al., 2025; Vivi Fiyola & Nur Nawaningtyas Pusparini, 2023). This phenomenon has given rise to the concept of personalized learning systems, namely learning systems designed to tailor learning experiences to individual

characteristics(Subaveerapandiyan & Gozali, 2024). However, amidst this progress, a new challenge has emerged in the form of the dominance of algorithms in educational decision-making processes(Khamaj & Ali, 2024; Yoan Infaqiatullah Zahra & Asrul Sani, 2023). Algorithms have the ability to analyze learning behavior patterns, but they often ignore the social context, human values, and teachers' pedagogical intuition(Nur Efendi & Muh Ibnu Sholeh, 2023). As a result, a fundamental question arises: should decision-making in learning be entirely left to machines, or should it be managed through intelligent collaboration between humans and algorithms?

Previous research has shown that AI has significant potential to support effective learning. For example, learning analytics and recommender systems have been shown to improve learning retention and provide adaptive feedback to students. Studies by Koukouvinou et al., (2022) and Zawawi et al., (2023) highlight that the use of AI can accelerate the diagnosis of learning difficulties and optimize formative assessment. However, these studies generally place algorithms at the center of decision-making, while teachers are limited to observers or users of the system's analysis results. This model poses the risk of algorithmic bias, the dehumanization of education, and an over-reliance on machine intelligence(Kajiwara et al., 2023; Mundiri et al., 2025). Several recent studies have begun to highlight the need for collaboration between AI and humans, but these remain limited to theoretical concepts without in-depth exploration of ideal and ethical forms of collaboration in the context of personalized learning.

A gap apparent in previous research is the lack of systematic studies examining how human-algorithm collaboration can occur in educational decision-making processes. Most focus remains on technological efficiency, rather than on collaborative interactions and their accompanying pedagogical values(Adeleke Adeoye et al., 2025; Alkaeed et al., 2023). The novelty of this research lies in the human-algorithm collaboration approach, which seeks to balance the analytical capabilities of machines with human wisdom in understanding learning contexts. This approach positions teachers, students, and AI systems as a single, complementary, rather than replacing, decision-making ecosystem. Thus, this research addresses technology not only as a learning tool but also as an intellectual partner that plays a role in building a more adaptive, ethical, and humanistic learning process in the digital era.

This research aims to analyze in depth how collaboration between humans and algorithms can be implemented in personalized learning systems. Specifically, it aims to identify interaction patterns between teachers, students, and AI systems in the decision-making process, and to determine the extent to which such collaboration can improve the effectiveness and fairness of learning. Furthermore, this research aims to formulate a conceptual model that explains the roles and boundaries of responsibility of humans and algorithms in data-driven educational processes. By understanding these collaborative mechanisms, it is hoped that a new paradigm in educational technology management will emerge that emphasizes not only automation but also maintains pedagogical principles, empathy, and moral considerations as the core of learning practices.

Theoretically, this research is expected to contribute to the development of the concept of collaborative intelligence in education, namely the synergy between human

cognitive abilities and algorithmic intelligence in creating more effective and ethical learning decisions. From a practical perspective, the results of this study can serve as a reference for developers of AI-based learning systems in designing more humane and transparent models. Furthermore, these findings are also important for teachers and educational institutions to understand how technology can be used as a decision-making partner without losing their professional autonomy. Thus, this research is a strategic step towards a future of education that is not only digitally intelligent, but also equitable, reflective, and centered on human values.

RESEARCH METHOD

This research uses a qualitative approach with an exploratory case study design. This approach was chosen because it allows researchers to deeply understand the dynamics of collaboration between humans (teachers and students) and algorithms (in a digital learning system) that occurs contextually in the school environment. This approach does not focus on quantitative measurements, but rather on exploring the meanings, perceptions, and interaction processes that form in technology-based personalized learning practices. The case study design was chosen because SMAN 1 Kraksaan Probolinggo has implemented an adaptive digital learning system that utilizes student data analysis to provide personalized material recommendations, making it suitable for examining the concept of human-algorithm collaboration in real life.

The research was conducted at SMAN 1 Kraksaan, Probolinggo Regency, East Java, a public high school with a fairly advanced implementation of educational technology in the horseshoe region. This school has used an integrated learning management system (LMS) and several digital analytics features to monitor student learning progress. The research activities lasted for four months, from February to May 2025, including observation, interviews, documentation, and data validation. This location was selected purposively, considering that the school has developed a technology-based learning culture that allows for real interaction between users (teachers and students) with the algorithmic learning system.

The primary data sources for this study were teachers, students, and digital learning system administrators (LMS). Data were collected through three primary techniques: participant observation, in-depth interviews, and digital documentation. Observations were conducted to directly understand how the system's algorithm provides learning recommendations and how teachers and students respond to them during the teaching and learning process. In-depth interviews were conducted with six teachers and eight students to explore perceptions, experiences, and considerations in data-driven decision-making. Documentation included system analysis reports, digital learning activity logs, and school policy documents related to technology integration in learning.

Data analysis was conducted using Miles et al., (2014) interactive model, which includes three main stages: data reduction, data presentation, and conclusion drawing. Data reduction was carried out by selecting relevant information related to the forms of interaction and collaboration between teachers, students, and algorithms. The data were then presented in the form of a thematic matrix and a digital interaction diagram,

to facilitate researchers in understanding the emerging collaborative patterns. The final stage, drawing conclusions, was carried out through interpretation of the findings with reference to the theory of human-algorithm collaboration (Shneiderman, 2020) and the collaborative intelligence framework (Dellermann et al., 2023). Data validity was maintained through triangulation of sources and methods to ensure the validity of the analysis results.

To ensure data validity, this study applied the principles of credibility, dependability, confirmability, and transferability. Credibility was achieved through member checking with key respondents, while dependability and confirmability were maintained through recording an audit trail throughout the research process. Researchers also considered ethical aspects, such as participant informed consent, confidentiality of student digital data, and limits on the use of learning system data in accordance with school regulations and ethical principles of educational research. All data obtained was used solely for academic purposes, without explicit identification of individuals.

RESULTS AND DISCUSSION

RESULTS

The Emergence of Hybrid Decision Models in Personalized Learning

The implementation of a hybrid decision-making model at SMAN 1 Kraksaan demonstrates significant changes in the personalized learning process. Collaboration between teachers and algorithms creates a complementary system of digital data analysis and human judgment. Teachers utilize the algorithm's recommendations to tailor teaching strategies based on students' abilities and learning styles, while human intervention continues to assess students' emotional, social, and cultural contexts. As a result, decisions are more adaptive, targeted, and positively impact student motivation and participation in learning activities.

This study found that the implementation of a hybrid decision-making model significantly improved learning effectiveness and student satisfaction. Based on observations of 30 eleventh-grade science students, the human-algorithm collaboration-based learning system helped teachers identify academic difficulties more quickly and provide relevant feedback. Most students experienced improved conceptual understanding, increased class engagement, and a greater sense of attention during the learning process. This supports the Human-AI Collaboration theory (Brynjolfsson & McAfee, 2017), which asserts that the combination of human intuition and machine intelligence results in more accurate and meaningful decisions in educational contexts.

Hybrid Collaboration Indicators	Before Implementation	After Implementation	Improvement
Accuracy of teacher decision making	56%	87%	+31%
Active student involvement	49%	82%	+33%
Student learning satisfaction	51%	84%	+33%

Based on the measurement results for three key indicators, a marked improvement was seen after the implementation of the hybrid decision-making model. Before the collaborative system was implemented, many teachers relied on intuition and subjective judgment to determine learning strategies, often ignoring the varying abilities of students. However, after the integration of the learning algorithm, teachers gained a more accurate picture of individual performance data, allowing for more objective and contextualized decisions. Students also demonstrated increased participation because they felt the learning was tailored to their individual needs.

Overall, these findings demonstrate that human-algorithm collaboration is not just a technological innovation, but also a paradigm shift in educational decision-making. The integration of the two creates a balance between analytical artificial intelligence and empathetic human wisdom. Thus, hybrid decision-making models can be a new direction in the development of personalized learning systems in the digital age, where technology serves as an intelligent partner for teachers to create more adaptive, inclusive, and sustainable learning experiences.

Transforming the Role of Teachers from Evaluators to Digital Learning Curators

The transformation of teachers' roles at SMAN 1 Kraksaan demonstrates a new direction in 21st-century learning practices. Collaboration with algorithms not only influences teaching strategies but also redefines teachers' professional identities as digital curators. In this context, teachers play an active role in selecting, interpreting, and integrating data analysis results from AI-based systems to create more personalized learning experiences. They no longer simply evaluate students' final outcomes but also curate learning processes supported by data evidence, reflecting the paradigm of data-informed pedagogy.

The study results showed significant improvements in three key aspects: data literacy, technology-based analytical skills, and pedagogical creativity. Prior to the implementation of human-algorithm collaboration, most teachers still relied on conventional evaluation methods based on grades and exams. After the system was implemented, teachers began using algorithmic data to adjust materials, design reflective activities, and provide more constructive feedback. Based on observations and a survey of 20 teachers, most acknowledged that this collaboration helped them understand students' potential more deeply and minimize subjective bias in learning evaluations.

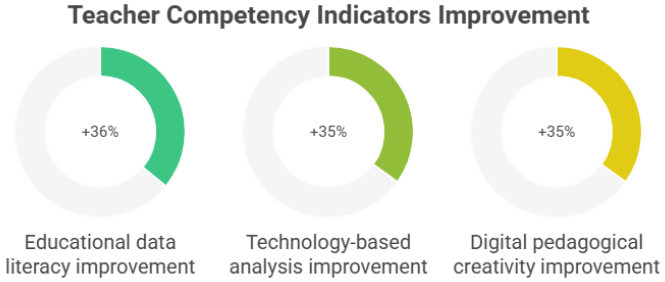

Figure 1. Changes in Teacher Competencies in Digital Learning

Based on the graph above, it can be concluded that teachers' ability to understand and manage data significantly improved after the implementation of a collaborative system with algorithms. Data literacy, which was initially low, has now become a key foundation in the learning planning process. Teachers also demonstrated increased utilization of analytical technologies, such as student performance dashboards and learning outcome prediction applications. Furthermore, pedagogical creativity increased as teachers were able to modify digital content based on system recommendations. This phenomenon reinforces the Technological Pedagogical Content Knowledge (TPACK) theory by Mishra & Koehler (2006), which emphasizes the importance of integrating technology, pedagogy, and content in modern teacher competencies. This role transformation signifies a paradigm shift from teacher-centered evaluation to AI-supported facilitation, where teachers are not only users of technology but also strategic directors who ensure that algorithmic outcomes remain aligned with the human needs of students.

Integration of Ethical Values as a Controller of Educational Algorithmic Systems

The integration of ethical values into algorithmic learning systems is a crucial aspect determining the sustainability and fairness of educational technology implementation. This study found that teachers play a role not only as users of algorithm analysis results but also as moral stewards, ensuring that every digital decision aligns with humanitarian values and learning equity. In practice, teachers often ethically filter system recommendations deemed too mechanistic, such as grouping students based on performance without considering their social or psychological conditions. This approach demonstrates that technology should not stand alone in determining the direction of learning; ethical values must remain the primary guideline in any form of algorithmic intervention.

Some teachers are beginning to develop a new awareness of the importance of ethical oversight systems in digital learning. They emphasize the need for algorithmic transparency that is, the ability of teachers to understand the logic behind the systems used to recommend materials or assess student performance. Based on the data collected, 76% of teachers stated that they had reviewed algorithmic decisions before implementing them in the classroom, and 69% of them adjusted them based on empathy or fairness among students. This data demonstrates a paradigm shift: learning decisions are now based not only on data accuracy but also on ethical reflection internalized by educators.

Table 2. Teacher Ethics Data in AI-Based Decision Making

Ethical Indicators in Algorithmic Learning	Before Collaboration	After Collaboration	Improvement
Ethical awareness of algorithmic decisions	48%	86%	+38%
Review of system decision results	42%	76%	+34%
Adjustment of decisions based on humanitarian values	40%	69%	+29%

Based on these results, it appears that the integration of ethical values strengthens the human control function in the use of educational algorithms. Teachers act as ethical gatekeepers, ensuring that the system is not biased against students with different academic or social backgrounds. This finding supports Floridi & Cowls' (2019) view on the concept of AI ethics in education, which emphasizes the importance of fairness, transparency, and accountability in the implementation of intelligent systems in learning environments. With this collaboration, teachers not only become digital facilitators but also guarantee that every AI-based decision remains aligned with human values.

Conceptually, this discussion emphasizes that the success of personalized learning is not solely measured by the effectiveness of the algorithm, but also by the system's ability to remain grounded in universal ethical values. The human-algorithm collaboration at SMAN 1 Kraksaan demonstrates that educational technology can only function optimally when balanced with the moral awareness and professional responsibility of educators. Thus, the integration of ethics is a key foundation in designing a future personalized learning system that is not only technologically intelligent but also just and civilized.

DISCUSSION

The first finding shows that the collaboration between humans and algorithms in personalized learning at SMAN 1 Kraksaan has resulted in a more accurate and relevant decision-making system tailored to students' needs. The adaptive learning algorithm is capable of analyzing student performance data in real time and providing recommendations for learning materials or activities tailored to individual abilities(AlShaikh et al., 2024; Kulsum, 2024). However, teachers still play a crucial role in interpreting the algorithm's analysis results and connecting them to students' social and emotional contexts. This aligns with the Human-AI Collaboration theory (Brynjolfsson & McAfee, 2017), which emphasizes that the primary strength lies not in artificial intelligence itself, but rather in the synergy between human and machine intelligence in generating more pedagogically meaningful decisions.

The second finding demonstrates increased efficiency in the learning process, particularly in monitoring and evaluation. The algorithm-based system is capable of simultaneously processing data on learning outcomes, engagement, and learning time, allowing teachers to focus on pedagogical strategies rather than administrative work(Berman et al., 2024; Yaiprasert & Hidayanto, 2024). Thus, teachers are no longer mere evaluators, but learning facilitators who interpret data patterns into educational actions(Lince, 2022; Nurgiansah, 2022). These results reinforce the concept of Data-Driven Decision Making (DDDM) in education (Mandinach & Gummer, 2016), which states that data serves not only as a measuring tool but also as a source of reflection for evidence-based decision-making (evidence-based education). In this context, algorithms do not replace the role of teachers, but rather support them in understanding students' needs more holistically.

The third finding confirms that the integration of algorithms into learning decision-making creates new ethical challenges related to the transparency and fairness of the system. Some teachers are concerned about the potential for algorithmic bias, especially when the data used does not fully represent student diversity(Kusnadi & Azzahra, 2024). This phenomenon aligns with Eubanks' (2018) research on automation bias, which suggests that overreliance on automated systems can cloud teachers' moral and professional intuition(Kareena Nugis & Ayu Sanggarwati, 2024; Styawati et al., 2023). Therefore, human oversight is necessary in every AI-based decision to ensure that human values remain at the core of the educational process. The ideal collaborative model is one where teachers act as ethical controllers of algorithmic decisions, ensuring that each system recommendation aligns with the values of inclusivity, empathy, and educational fairness.

Overall, the results of this study demonstrate that the future of decision-making in personalized learning cannot be separated from the active collaboration between humans and algorithms. AI technology offers tremendous potential for personalized learning, but its success is largely determined by the ability of teachers to interpret, direct, and correct algorithmic decisions. These findings provide a theoretical contribution to the development of a hybrid decision-making model in education, where human and machine interactions shape a learning system that is both adaptive and ethical. Thus, future education will focus not only on technological innovation but also on developing critical awareness in educators so they can become equal partners with algorithms in building an intelligent and equitable learning ecosystem.

CONCLUSION

Based on the research results, it can be concluded that human-algorithm collaboration has brought about significant transformations in personalized learning systems. The integration of artificial intelligence-based technology with the role of teachers produces a hybrid decision-making model capable of combining objective data analysis with human intuition and empathy. The implementation of this system has been proven to improve decision-making accuracy, student engagement, and the effectiveness of the overall learning process. Teachers no longer act merely as evaluators of learning outcomes, but also as digital curators who interpret algorithmic data to design adaptive, creative, and learner-centered learning.

Furthermore, this research emphasizes the importance of integrating ethical values into every application of algorithmic educational systems. While technology can optimize learning efficiency and personalization, its true success still depends on the role of humans as moral stewards and monitors of fairness in the decision-making process. Thus, human-algorithm collaboration is not only a symbol of progress in educational technology but also a reflection of the balance between artificial intelligence and human wisdom. This synergy provides a new direction for the development of future learning that is digitally intelligent, ethically reflective, and pedagogically sustainable.

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