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Intelligent Systems, Individual Minds: How AI Is Reorganising Learning

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ABSTRACT

This study examines the use of artificial intelligence in education with regard to potentials and limitations. AI changes learning processes through pattern recognition, adaptive control and personalised feedback. Methodologically, the work is based on a literature analysis and case studies from different contexts. The research question focusses on whether AI promotes individual learning when different preferences are taken into account. Two hypotheses were tested. The results show that adaptive systems can increase motivation and performance and stabilise education in crisis situations. Quantitative meta-analyses confirm that learners achieve significantly better results on average in intelligent tutorial environments than in traditional formats. International comparative studies such as the OECD PISA analyses also point to measurable differences in performance in favour of digital learning platforms with AI components. At the same time, the concept of learning types remains scientifically controversial, which is why the second finding is only valid to a limited extent. In addition, ethical and organisational framework conditions are proving to be key factors. International guidelines call for transparency and accountability, while national analyses point to structural inertia. The study makes it clear that AI can modernise education if systems personalise in a targeted manner and thereby improve learning processes. At the same time, it shows that potential can only be realised if ethical standards are in place and institutional structures enable reforms.

Keywords: Artificial Intelligence, Education, Learning Preferences, Adaptive Systems, Ethical Frameworks, Lifelong Learning, Digital Transformation

INTRODUCTION

Learning continuously moves between the known and the unknown. The spread of artificial intelligence alters this relationship. AI transforms not only pedagogical tools but also the fundamental conditions of learning. Systems identify patterns, structure data, and adapt content, thereby assuming functions traditionally associated with teachers. This shift creates opportunities while simultaneously raising questions concerning legitimacy, control, and impact. International analyses emphasise the potential. Holmes et al. (2019) show that AI can control and individualise learning processes in a differentiated way. In their review, Chen et al. (2020) emphasise the ability of AI-supported systems to adaptively prepare content and provide feedback in real time. The European Commission (2020) emphasises that innovations are only viable if they are based on principles of trustworthy AI. International comparative studies such as PISA also make it clear that digital learning

environments with AI components can generate measurable differences in performance (OECD, 2021). The most recent evaluation of the 2022 PISA study for Germany confirms these findings and shows that there are considerable challenges, but also opportunities, through the targeted use of digital systems, particularly in the area of scientific skills (Lewalter et al., 2023; Federal Statistical Office, 2023).

The debate is also intense in German-speaking countries. De Witt et al. (2023) categorise AI as a strategic challenge for education management. Schleiss et al. (2023) develop scenarios that visualise the opportunities and risks of future developments. Sabitzer, Hörmann and Kuka (2024) problematise the frivolous use of AI and question the seriousness of didactic integration. Knaus (2023) speaks of a collaborative attempt at enlightenment that demands social reflection. Schreier (2025) emphasises the need for digital-reflective judgement in order to shape education responsibly in the age of AI. Oberdieck and Moch (2024) also provide a systematic analysis of the potential of lifelong learning with AI and make it clear that personalisation, adaptive environments and intelligent tutoring systems are key levers. The concept of learning types remains a central area of tension. Pashler et al. (2009) show that the empirical basis is weak. Newton and Miah (2017) declare the model a myth. Nevertheless, teachers use it to categorise heterogeneity. AI exacerbates this contradiction by recognising differences in learning behaviour and reacting to them immediately, even if the theoretical basis remains uncertain.

The research question of this thesis is how AI can promote individual learning when different types of learning behaviour are taken into account. The aim is to gain an integrated picture through systematic literature analysis and selected case studies. Didactic, technological and ethical perspectives are included, based on international institutions such as OECD (2021) and UNESCO (2021), the international research situation and current German-language contributions.

Two hypotheses guide the analysis. Firstly, that AI-supported systems increase learning outcomes when they respond specifically to learning styles. Secondly, that learners with clear preferences benefit more than learners without a clear categorisation.

The article follows a fixed structure. Firstly, the current state of research is presented. This is followed by methods and results. The discussion examines hypotheses, opportunities and risks. Limitations are shown separately. The article concludes with implications for research, practice and policy.

LITERATURE REVIEW

Research into artificial intelligence in education has gained considerable momentum in recent years. Numerous studies have shown that AI-based systems can structure, individualise and accelerate learning processes. Chen, Chen and Lin (2020) provide a comprehensive overview of fields of application and illustrate that adaptive systems promote learning progress through continuous adaptation. Holmes, Bialik and Fadel (2019) argue that AI is transforming the role of teachers by opening up new opportunities for differentiation without completely replacing them. Zawacki-Richter et al. (2019), on the other hand, criticise the research situation to date, as technical aspects dominate and the pedagogical dimension is often neglected.

International comparative studies provide additional robust evidence. OECD PISA analyses (2021) show that digital learning platforms with AI components cause measurable differences in performance, particularly in science subjects. This confirms findings from controlled studies at systemic level. The German PISA evaluation 2022 (Lewalter et al. 2023; Federal Statistical Office, 2023) points in a similar direction, but at the same time highlights structural deficits. Although AI-supported systems can favour performance gains, differences in equipment and institutional

barriers remain key inhibiting factors. These findings link international evidence with national education policy and make it clear that the potential of AI can only be realised if technological innovation is embedded in organisational reforms. The concept of learning types remains a controversial area. Pashler et al. (2009) show that empirical evidence for positive effects on learning performance is lacking. Newton and Miah (2017) confirm this diagnosis and attribute the attractiveness of the model to its simplicity. Nevertheless, it is widely used in practice to organise heterogeneity. AI exacerbates this contradiction, as systems adaptively take into account differences in learning behaviour, although the theoretical foundation remains fragile. This tension between practical applicability and scientific weakness is a central touchstone for current research.

AI debates now focus on ethics. Public trust requires transparency, fairness, and accountability (European Commission, 2020). UNESCO (2021) stresses the role of global governance in sustaining educational innovation. OECD (2021) points to competences, assessment, and curriculum reform. Critics warn that implementation often lags behind. Sabitzer, Hörmann, and Kuka (2024) find that schools usually adopt AI only on the surface. Knaus (2023) calls for wider public debate on both ethical and technological aspects. Schreier (2025) stresses reflective judgement, as rules alone cannot ensure responsible use. German-language scholarship widens the scope. De Witt, Gloerfeld, and Wrede (2023) see AI as a strategic management tool and promote closer alignment between didactics and technology. Schleiss et al. (2023) outline scenarios showing both benefits and risks of future change. Schmohl, Watanabe, and Schelling (2023) argue that institutional barriers often outweigh technical limits in universities. Oberdieck and Moch (2024) expand the view to lifelong learning, showing the growing role of personalised pathways, adaptive systems, and intelligent tutoring beyond schools. Case studies illustrate the practical implementation. Huang et al. (2020) use the example of China to document how flexible digital learning concepts contributed to safeguarding educational processes during the pandemic. Mergel (2021) analyses the German administration and shows that institutional inertia significantly delays digital transformation. These examples make it clear that technological potential only has a limited impact without institutional adaptation.

The literature thus highlights three central areas of tension. Firstly, the promise of personalised learning in contrast to the fragile theory of learning types. Secondly, the discrepancy between demonstrable effectiveness in international studies and limited implementation in national education systems. Thirdly, the dynamics of technological innovation in conflict with ethical guard rails and institutional structures. These tensions characterise the current research situation and show that AI will only be effective in the education system if technical developments are combined with pedagogical substance and political willingness to reform.

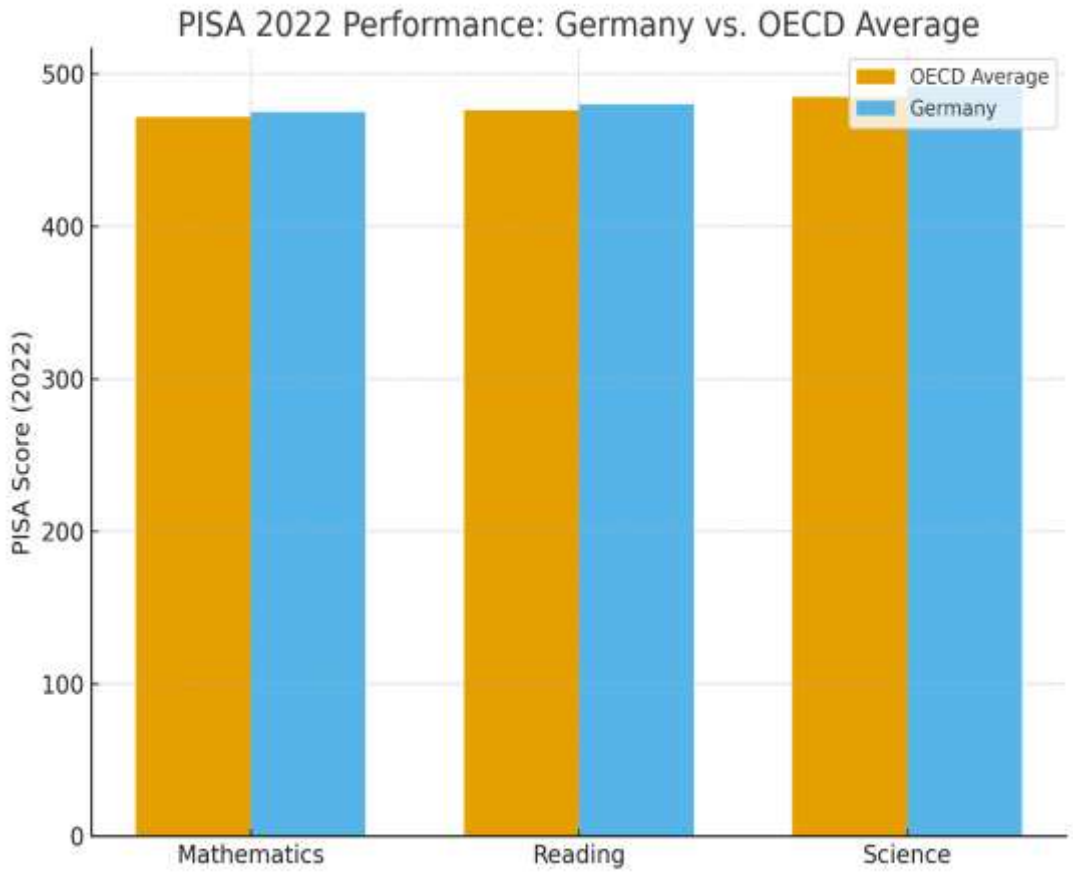

Figure 1: Comparison of the 2022 PISA results in Germany with the OECD average. In all areas tested (maths, reading and science), German scores are slightly above the international average, particularly in the area of science. The data illustrates both the ability of German educational results to catch up with international standards and the existing challenges associated with the integration of digital and AI-supported learning systems (OECD, 2021; Lewalter et al. 2023; Federal Statistical Office, 2023).

MATERIALS & METHODS

The study follows a qualitative design. It is based on a combination of systematic literature analyses and case studies. This approach makes it possible to critically summarise the state of research and at the same time shed light on practical implementation. Chen, Chen and Lin (2020) and Zawacki-Richter et al. (2019) show that this combination is suitable for capturing both technical and pedagogical dimensions. Oberdieck and Moch (2024) also show that the combination of literature review and case studies creates the added value of a triangulated perspective.

The literature analysis is based on peer-reviewed publications and key documents from international institutions. Included are OECD (2021), UNESCO (2021) and the guidelines of the European Commission (2020). In addition, studies addressing the opportunities, limitations, and ethical challenges of AI in education are included (Holmes et al., 2019; Pashler et al., 2009; Newton & Miah, 2017). The German-language debate extends this view by considering institutional and societal dimensions (De Witt et al., 2023; Schleiss et al., 2023; Sabitzer et al., 2024; Knaus, 2023; Schreier, 2025; Schmohl et al., 2023; Wollersheim et al., 2021). The selection followed clear criteria. Publications between 2009 and 2025 with a verifiable empirical or theoretical basis were considered. Popular science texts without peer review were excluded. The analysis was thematic. The focus was on the effectiveness of AI learning systems, the theoretical foundation of the learning type debate and the ethical and institutional framework conditions.

The case studies provide additional insights. Huang et al. (2020) document the Chinese model of flexible learning during the pandemic. Mergel (2021) uses the example of the German administration to illustrate the structural barriers to digital transformation. Schmohl, Watanabe and Schelling (2023) analyse universities and reveal institutional blockages. Oberdieck and Moch (2024) expand this framework by including international case studies on personalised learning, adaptive environments and intelligent tutoring systems. The analysis follows the principle of thematic summarisation. Core statements are organised according to the research question and hypotheses. Confirmations and contradictions are considered equally. The aim is a systematic presentation that not only reflects the current state of research, but also critically analyses it.

The methodological approach shows strengths and limitations. Its strength lies in the triangulation of international institutions, scientific literature and case studies. Its weakness lies in the risk of publication bias and the limited generalisability of individual case studies. These limitations are clearly identified in the chapter on limitations.

RESULTS

The analysis of the literature and case studies shows a clear picture. Three topics dominate. Firstly, the effectiveness of AI-supported learning. Secondly, the role of the learning type concept. Thirdly, the normative and institutional framework conditions. AI systems make learning more flexible. Chen et al. (2020) find that adaptive systems tailor content and speed up progress. Holmes, Bialik, and Fadel (2019) note greater learner involvement when content is personalised. Oberdieck and Moch (2024) confirm this in international case studies. Personalised pathways, adaptive settings, and tutoring systems raise motivation and performance. During the COVID-19 pandemic, Huang et al. (2020) show that flexible structures supported the stability of education systems.

In addition to these qualitative findings, there is also robust quantitative evidence. In a meta-analysis, VanLehn (2011) shows that learners in intelligent tutoring systems achieve better results on average by around 0.76 standard deviations than in traditional formats. OECD PISA analyses (2021) show that students in science subjects achieve significantly higher scores when using digital platforms with AI components. These quantitative results support the findings of Chen et al. (2020), Holmes et al. (2019) and Oberdieck & Moch (2024), according to which personalised systems increase motivation and performance.

The concept of learning types remains contradictory. Pashler et al. (2009) provide no evidence of improved learning outcomes. Newton and Miah (2017) support this criticism. Nevertheless, the literature shows that many systems implicitly respond to differences in learning behaviour. This leads to a paradoxical situation. Systems adapt content even though the scientific basis remains weak. The ethical and institutional framework conditions are crucial. The European Commission (2020) calls for AI systems to be trustworthy, transparent and fair. UNESCO (2021) emphasises the need for global standards. OECD (2021) adds to the debate by focussing on skills and performance assessment. National analyses confirm these findings. Mergel (2021) shows that the digital transformation in Germany is being held back by institutional inertia. Schmohl, Watanabe and Schelling (2023) identify opportunities in universities, but also point out structural hurdles. De Witt, Gloerfeld and Wrede (2023) emphasise that strategic management is essential.

AI improves learning processes if it is used in a personalised way. The learning type concept remains theoretically fragile and empirically insufficiently substantiated. Ethical and institutional questions determine whether potentials are realised or blocked.

DISCUSSION

The results support the first hypothesis. AI-supported systems improve learning

outcomes when they are used in a personalised way. Both qualitative case studies and quantitative analyses indicate that adaptive systems sustainably promote learning processes. The advantage of personalised paths, adaptive environments and intelligent tutoring systems lies in the possibility of increasing motivation and stabilising education even under crisis conditions. On the other hand, the second hypothesis can only be confirmed to a limited extent. Learners with clear preferences appear to benefit more, but the theoretical basis of learning types remains weak. This reveals a tension between empirical benefits and a lack of conceptual foundation. While practice indicates that systems react factually to differences in learning behaviour, theory lacks robust evidence. International comparative research also points to differences in implementation. OECD PISA analyses show that digital learning environments with AI components enable measurable performance gains. However, the German PISA evaluation 2022 shows that this potential is only partially utilised in the national context. Institutional barriers, differences in digital equipment and structural inertia prevent the positive findings of international studies from taking full effect in Germany (Lewalter et al., 2023; Federal Statistical Office, 2023). This exacerbates the tension between international evidence and national practice. The debate therefore has a dual perspective. Advocates emphasise the potential of personalised systems that can be used responsibly through transparent guidelines and ethical standards. They point to international guidelines that are intended to ensure fair and comprehensible use and see AI as an instrument that can modernise education systems and make them fairer. Critical voices, on the other hand, emphasise that unsecured assumptions such as the concept of learning types create methodological weaknesses and that institutional inertia is a significant brake on innovation. There is also a risk that a lack of transparency and inadequate governance will undermine trust in AI-supported education systems. This juxtaposition gives rise to three central tensions. On the one hand, the promise of personalised learning in contrast to the fragile theory of learning types. On the other hand, the dynamics of technological innovation in conflict with institutional inertia. Finally, the prospect of efficiency gains and participation, which remains inextricably linked to ethical standards and effective governance.

These tensions make it clear that AI will only strengthen education systems in the long term if it is integrated in a didactically sound, ethically sound and institutionally supported manner. Without these prerequisites, the potential remains fragmentary and the risks of misuse come to the fore.

LIMITATIONS

The study has several limitations that are important for the interpretation of the results. On the one hand, the analysis is deliberately based on peer-reviewed literature and key documents from international institutions, which ensures a solid database. On the other hand, this results in a publication bias, as unpublished or contradictory studies are excluded. The selection of case studies offers the advantage of visualising key developments and providing practical insights. At the same time, it is geographically and thematically limited, as the focus is on Europe and individual examples from Asia. It was therefore not possible to achieve a comprehensive global perspective, which limits the generalisability. A further area of tension arises from the role of learning types. The inclusion of this concept makes pedagogical practices understandable and shows how AI actually addresses differences in learning behaviour. At the same time, the theoretical foundation remains fragile, which relativises the significance of the findings.

The methodological approach is also ambivalent. The qualitative approach allows a condensed presentation of opportunities, risks and institutional framework conditions, but inevitably leads to less precision in terms

of effect sizes or statistical correlations. Quantitative impact analyses would have provided additional clarity, but were not included in the study. Overall, these limitations show that although the results provide robust indications of the potential of AI in education, they also require cautious interpretation. They highlight the points where further research needs to start in order to better illuminate the balance between conceptual viability and practical effectiveness.

CONCLUSION

The analysis shows that AI is changing learning. Systems personalise content, control learning paths and react flexibly to differences. Studies show that this increases motivation and results (Chen et al., 2020; Holmes et al., 2019; Oberdieck & Moch, 2024).

The concept of learning types remains a fragile foundation. Pashler et al. (2009) and Newton and Miah (2017) refute its evidence. Nevertheless, AI systems use differences in learning behaviour to make adjustments. The contradiction between benefits in practice and weak theory remains. Embedding in ethical and institutional frameworks is crucial. European guidelines (European Commission, 2020; OECD, 2021; UNESCO, 2021) set standards for trust, transparency and fairness. At the same time, national analyses show inertia and blockages (Mergel, 2021; Schmohl et al., 2023). Reflective judgement and strategic control are gaining in importance (De Witt et al., 2023; Schreier, 2025).

The work confirms two key findings. Firstly, that AI can improve learning processes if systems personalise in a targeted manner. Secondly, that the potential can only be realised if ethical guidelines and institutional structures are in place. This has clear implications. Research must continue to empirically test the effect of adaptive systems. Practice needs guidelines for didactically sound use. Politics must create a framework that enables innovation and prevents misuse. AI opens up opportunities for education, but its success depends on the ability to combine technological dynamism with pedagogical substance and ethical responsibility.

Info boxes

SUMMARY

- Stakeholder governance requires a balance between rules and freedom
- Order can voluntarily bundle legitimate interests
- Trust, clear rights and open networks ensure practical effectiveness

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- Markets are not obstacles, but resonance spaces for co-design
- Over-regulation stifles personal responsibility and local adaptation
- Decentralised knowledge remains unused if participation is formalised

Recommendations For Action

- Create incentives for voluntary co-operation and clustering
- Clearly define ownership and utilisation rights
- Make conflicts visible instead of hiding them behind bureaucracy

Declaration by Authors

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Enrico Moch holds a doctorate in economics and teaches as a lecturer at various universities, including the DHBW Ravensburg and as an assistant professor at the IIC University of Technology. As Academic Director of the GrandEdu Research School in Germany, he combines academic excellence with practice-orientated teaching. His research interests include the Austrian School of Economics, AI governance, technical data protection and

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