AI-based Learning Assistants: Enhancing Math Learning for Migrant Students in German Schools

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***Abstract*— Increasing migration leads the education landscape to face the challenge of integrating children into the school system, accounting for inherent disadvantages. On average, as nearly half of them face socio-economic disadvantages, a persistent performance disparity was observed compared to domestic students. Remarkably, even after mitigating the influence of socioeconomic status, immigrant students' scores remained inferior. From March to May 2023, the AI Education (AIEDN) research project investigated how an AI-based learning assistant can compensate for existing impediments by enabling a better understanding through video-based learning. For this study, 275 students were selected from two secondary schools (N=137) and two grammar schools (N=138) in Baden-Württemberg, Germany. The experiment tested the extent to which learners solve more tasks, build broader (transfer) knowledge, and retain it. Students were repeatedly tested on mathematical problems, where the control group did not have access to the AI assistant. In contrast, the other group used the AI assistant to solve the problems. The students' performances from both school groups were statistically tested using t-tests. Within the test group of grammar schools, a significant change in the results between the two test days existed (T(41)=-2,28; p<.01) when the AI tool was used. In contrast, the control group showed no significant change T(37)=-.42; p>.05; d=.07) in performance. However, the results were insignificant for the secondary school students, as the given tasks and video content were considered too demanding. Further research is needed to determine AIEDN's performance for other target groups.**

Keywords*— *AI, AI learning assistant, AI education, video-based learning, self-learning, migration, migrant students

I. Introduction

The recorded 281 million migrants, representing 3.6 percent of the world's population today [1], contain 36 million school children [2]. The European Union, one of the main destinations for people seeking refuge and asylum since 2015, needs to develop strategies for their education equality, along with cultural integration [3], respecting diversity issues [4].

In recent years, the unequal distribution of educational resources among divergent societal groups [5], especially for students with a migrant background, has gained more visibility since school education signifies the most incisive ramifications on their cognitive development [6]. However, PISA data consistently reveals that European countries still experience problems with social and educational integration of the population with a migration background, leading to performance gaps in school compared to their native counterparts [3;5]. In several nations, immigrant students face significantly more socioeconomic disparities. Notably, Germany falls below the OECD average, where 42% of immigrant students have been noted to have such difficulties, whereas, for native Germans, it is 18%. [6]. The apparent shortage of teachers in proportion to the growing numbers of adolescents from a migrant background, particularly in Germany, exacerbates the situation further [9].

The critical juncture for immigrant students is not merely their point of entry but the subsequent decisions made by educators and school systems regarding tailored programs and support [4]. PISA data underscores the influence of personal circumstances, such as socio-economic status, gender, and immigration status, in creating privileges or barriers that affect academic performance [8]. The "immigration gap" in mathematics performance reveals that non-immigrant students outperformed immigrant students on average across OECD countries [6].

Information technologies like e-learning tools and Massive Open Online Courses (MOOCs) are pivotal in education, simplifying knowledge access and transforming learning [9]. AI has firmly entrenched itself as an indispensable tool in higher education. Scholars unanimously underscore AI solutions' myriad possibilities to reshape the teaching and learning landscape [10; 11]. This becomes particularly significant as traditional teaching methods grapple with declining student enrollments [12], necessitating cost-effective educational approaches [13].

Incorporating AI-enhanced teaching methods offers numerous advantages for educators and students. Scientists [14] emphasize how AI assistants can alleviate instructors' burdens by automating assessment, management, and feedback processes. Students, in turn, benefit from individualized learning paths and personalized instructions developed by AI assistants based on existing learning materials, prior knowledge, skills, and pace [11].

Thus, to investigate how AI assistants can aid student learning, the AIEDN study engaged 275 students across two distinct educational settings, examining the potential of a semantic AI assistant to address inherent weaknesses more effectively. The study aimed to facilitate and reinforce enhanced mathematical understanding through video-based learning. Preliminary findings suggest that instructional videos contribute positively to learning outcomes, fostering sustained retention of procedural knowledge [15;16].

II. Methodology

The quantitative experiment from March to May 2023 involved students from 9th and 11th standards in grammar and secondary schools. Grammar schools comprise lower and upper secondary education from years five to 12 or 13, preparing students for the general higher education entrance qualification (Abitur). Ranging from years five to ten, secondary schools provide lower secondary level education with the opportunity to join an apprenticeship upon graduation [17]. Participants were tasked with solving

979-8-3503-5409-6/24/$31.00 ©2024 IEEE
DOI 10.1109/CAI59869.2024.00035

mathematical problems on an unfamiliar topic, either utilizing the AIEDN AI assistant or an equivalent simulation relying on conventional keyword search methods. A follow-up test with similar tasks was administered 6-8 days later without any assistance to assess the impact on learning.

A. Research Hypotheses

The AIEDN AI learning assistant provides a more personalized learning approach by delivering tailored (mathematical) content, elevating engagement with the material. Although it fails to achieve complete personalization, the assistant imparts substantial individualization to users. Consequently, the AI learning assistant is anticipated to yield positive learning effects and enhance learning processes more efficiently than conventional video-based learning.

These considerations lead to three hypotheses, scrutinized through a mixed-methods study:

1. Learners who utilize the AI learning assistant or have learned with it can concurrently complete more tasks than those who did not use the AI assistant or who learned without it.
2. Learners who employed the AI learning assistant can cultivate a deeper understanding of knowledge and apply it more effectively to transfer tasks than learners who did not utilize the AI learning assistant.
3. Learners who engaged with the AI learning assistant during their learning experience can exhibit prolonged retention of acquired knowledge compared to those who learned without AI assistance.

B. Research Design

Sample

This empirical investigation examined a cohort of 275 students from four educational institutions in Baden-Württemberg, Germany, comprising two secondary and two grammar schools. The experiments at the two school types were executed independently, with 139 students at grammar schools and 137 students at secondary schools, allowing for the testing of the AI assistant on a diverse student population. Rigorous attention was paid to maintaining a balanced gender distribution across the sample. The selection of schools was confined to Baden-Württemberg to eliminate variations in curricula among federal states, ensuring comparability.

Students from grade 11 in grammar schools and grade 9 in secondary schools, who were due to graduate soon, were chosen, ensuring equal or heightened participatory motivation due to the potential repetition of learning material for impending final exams. Possible age-related differences in maturity and learning development were mitigated by focusing on a single grade level per experiment.

Experimental setup

To empirically test the research hypotheses, students from both grade levels were given a fixed set of seven (for secondary schools) or eight (for grammar schools) mathematical problems on an unfamiliar topic to complete within 90 minutes, replicating an exam format. Depending on the assigned test group, students familiarized themselves with the subject using the AIEDN AI assistant or through a regular keyword search on a "simulated AIEDN video platform." Both platforms operated with content from Math YouTuber Daniel Jung. Randomized assignment ensured unbiased distribution to the test or control group. The mathematical tasks remained consistent between the two groups to maintain comparability.

The choice of mathematics as the subject of study was driven by its objectivity, allowing for standardized evaluation and comparison. To gauge the learning effect, the test was repeated 6 to 8 days later with similar tasks of the same scope, this time without the aid of the AI assistant. All responses were recorded on paper, mirroring a typical school day, ensuring constant visibility of questions, and allowing for flexible processing.

Score Grading

In the context of a German higher education entrance qualification (Abitur), three correctors are involved in carrying out a single correction run. However, due to the small-time window for correction, a different approach was chosen for the study, in which a group of correctors worked on the exams. A total of 17 people were involved in the correction process, including employees of the companies thingsTHINKING and Daniel Jung Media with a mathematical background (computer science and mathematics studies) as well as students at the Karlsruhe Institute of Technology and the University of Education in Karlsruhe with a STEM degree. 20% of the exams were corrected twice to eliminate average bias in the assessment.

The correction guide was based on the correction sheets for the Abitur exams in Baden-Württemberg from 2022. As the exams were not designed to be completed in the given time, more emphasis had to be placed on the small-step processing of the tasks than on the complete solution. Instead of awarding points for complete subtasks, the minimum steps required were identified and points awarded. This encouraged greater standardization and allowed for the desired consideration of sub-steps. Overall, points were awarded one to six points per (sub)task.

Prototype

As part of this study, a prototype based on Streamlit was realized. Streamlit is a Python-based library that enables the display of text, interaction elements, and output of AI models, as well as the visualization of data and model performance, and it can adjust model input parameters via the user interface. The use of Streamlit enables the rapid creation of simple web applications for AI models. The AI learning assistant's user interface was intentionally created to be simplistic and free of distractions. No modifications were made to the prototype during data collection. This was necessary to draw appropriate conclusions and ensure comparability between the AI assistant and control groups.

The prototype's database consisted exclusively of mathematical explanatory videos by Daniel Jung. The videos' voice recordings were transcribed and divided into segmented sections. The resulting transcripts were transferred to the semantic AI environment. The corresponding video, the associated timestamp, and other metadata, such as the subject area, were stored for each text segment.

A semantic fingerprint was created for each sentence in the transcripts, representing the sentence's content at the meaning level. This is the core function of thingsTHINKING GmbH's semantha® AI, on which the prototype is based. This semantic fingerprint enables the AI to understand the content of the video on a semantic level and to generate relevant answers to queries. The effectiveness of the semantic search function increases in proportion to the amount of context provided for the question asked. Participants in the AI group were instructed to ask the AI-based learning assistant questions with a high degree of accuracy, similar to interacting with a human tutor. Participants in the control group were asked to enter keywords to get relevant results, , similar to a conventional search engine.

III. Results

To examine any performance improvement associated with using the AI learning assistant, a series of t-tests was conducted, considering variables such as the student's gender, migration background, and type of school.

A. Analysis by gender

The sample analysis shows a significant increase in learning for both genders among grammar school students supported by the AI assistant. It was observed that male students showed a medium effect size (d=0.35) with a tendency towards improvement through the use of the AI tool ($T(28)=-1.90$; $p<0.05$) within the two test days. Female students also showed similar trends of improvement ($M1=15.76$; $SD1=13.32$; $M2=21.33$; $SD2=23.46$). Thus, participants from both genders at the grammar school had a medium (d=.33) significant change in the results ($T(36)=-1.99$; $p<0.05$), emphasizing the effectiveness of learning with the help of the learning assistant for both genders.

In contrast, the control groups, who took the tests without the AIEDN AI tool in the grammar school, showed no significant change in results between the two test days. Neither the male students ($T(35)=0.34$; $p>0.05$; $d=0.06$) nor the female students ($T(31)=-1.05$; $p>0.05$; $d=0.19$) had any signs of improvement when both test days were compared.

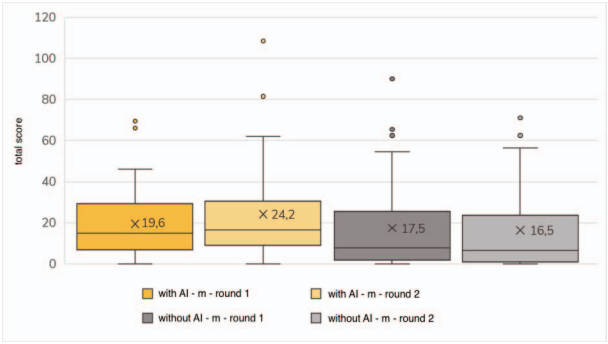

Fig. 1. Evaluation of male students at grammar schools with and without usage of the AI learning assistant

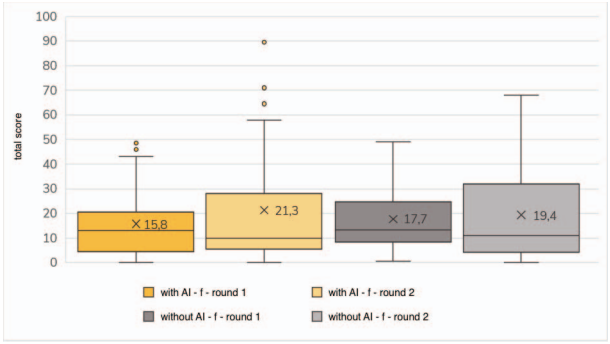

Fig. 2. Evaluation of female students at grammar schools with and without usage of the AI learning assistant

Within secondary schools, an analysis of the mean scores obtained shows no improvement in the performance spectrum for either gender. Neither male ($T(35)=-1.22$; $p>0.05$; d=.20) nor female ($T(30)=-1.58$; $p>0.05$, $d=0.28$) participants achieved significant improvements in learning performance with the help of AIEDN. In comparison, in the control groups of secondary schools that did not work with the AI assistant, the average score achieved only increased for the female subjects ($M1=5.36$; $SD1=5.79$; $M2=8.63$; $SD2=9.85$), while the male students lost points ($M1=3.83$; $SD1=6.48$; $M2=2.82$; $SD2=7.10$). The non-significant improvement in the performance of the male subjects is also confirmed by the t-test ($T(29)=1.04$; $p>0.05$; $d=0.19$). In contrast, the female students were not only able to improve their significantly higher average score without the use of the AI assistant but also showed a significant change in scores and an increase in overall learning performance ($T(34)=-2.20$; $p<0.05$) with a medium effect size (d=0.37).

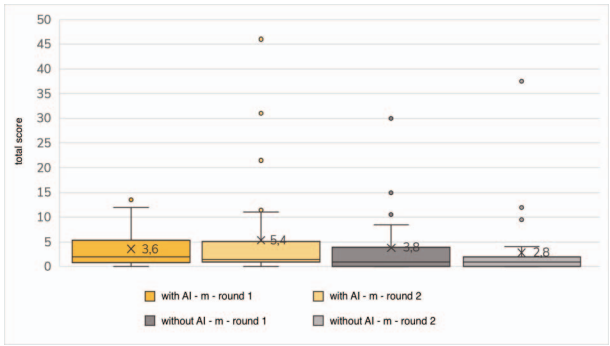

Fig. 3. Evaluation of male students at secondary schools with and without usage of the AI learning assistant

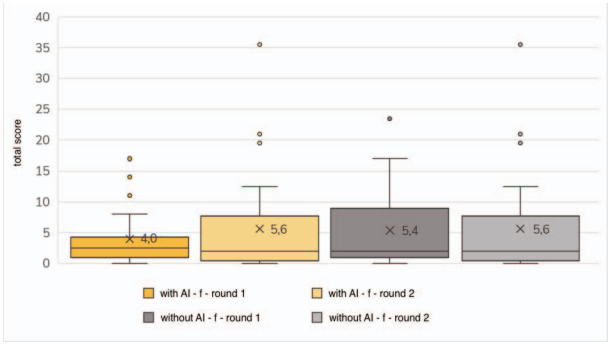

Fig. 4. Evaluation of female students at secondary schools with and without usage of the AI learning assistant

B. *Analysis by migration background*

Of the 275 participants in the study, 162, or about 59% of all pupils, were migrants. These 162 participants were almost evenly distributed between the two types of schools: 80 were in grammar schools, and 82 were in secondary schools.

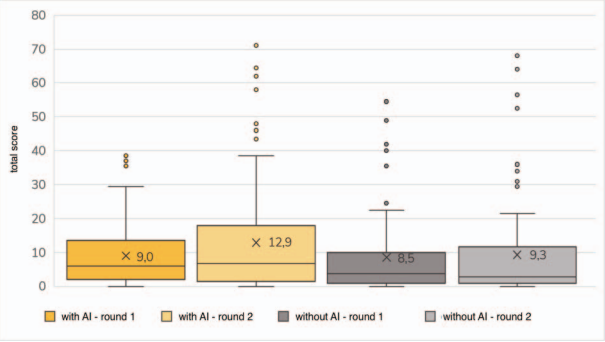

Fig. 5. Evaluation of total participants with a migration background with and without the use of the AI learning assistant

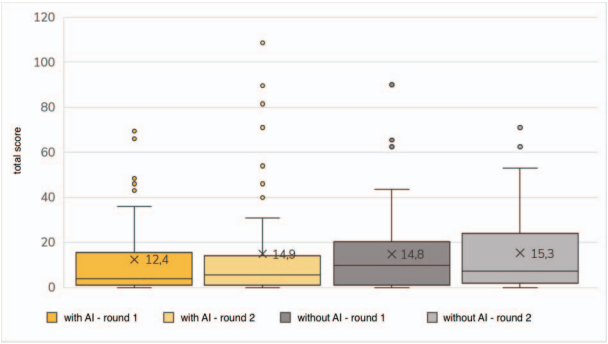

Fig. 6. Evaluation of total participants without a migration background with and without the use of the AI learning assistant

The evaluation of the influence of the AI assistant on learning performance, considering the migrant background of the students, showed positive results in the test group of grammar schools that used the AI. Concerning the mean scores over the two survey periods (M1=13.81; SD1=10.28; M2=19.34; SD2=18.78), a continuous increase in the total score was observed with a medium effect size (d=0.35). The analysis of the corresponding t-test confirmed the significance of the change in scores due to the AI assistant ($T(41)=-2.28$; $p<0.01$). In comparison, the secondary school control group with a migrant background, which did not use AIEDN, showed only a marginal increase in the mean scores achieved (M1=13.78; SD1=15.65; M2=14.28; SD2=19.67). Overall, however, there was no significant change or increase in scores ($T(37)=-0.42$; $p>0.05$; d=0.07).

Furthermore, the analysis of the sample of secondary school students without a migration background shows that the AI assistant does not improve learning performance here either. While the grammar school group with AI improved their overall score on average over both test days (M1=24.54; SD1=21.32; M2=29.17; SD2=31.50), the control group slightly deteriorated (M1=20.74; SD1=20.32; M2=20.34; SD2=20.18). However, neither the test group with AI ($T(22)=-1.50$; $p>0.05$; d=0.31) nor the control group without AI ($T(33)=0.11$; $p>0.05$; d=0.02) showed significant improvements in learning. In the subsequent secondary school study, there was a constant, albeit minimal, increase in total scores between the two survey dates for all test and control groups. However, the test group with a migrant background did not achieve a significant performance improvement ($T(37)=-1.48$; $p>0.05$) through the use of the AI assistant, despite the small effect size (d=.24), measured by the mean of the two survey times (M1=3.68; SD1=4.10; M2=5.80; SD2=9.82). The same characteristics are reflected in the mean values of the test group without a migration background (M1=3.67; SD=4.27; M2=4.70; SD2=6.86). The evaluation of the t-test also confirms that, despite the use of the AI assistant, no optimization of learning could be achieved ($T(31)=-1.16$; $p>0.05$; d=0.21).

In contrast, the mean total score achieved by the non-migrant control group, which did not have a supporting AI assistant, was significantly higher between study day 1 (M1=5.68; SD1=8.33) and study day 2 (M2=7.59; SD2=11.32) than in the migrant control group (M1=4.00; SD1=4.63; M2=4.99; SD2=7.70). However, no positive correlation could be found between the increase in performance of the subjects in the control group with a migrant background ($T(43)=-0.81$; $p>0.05$; d=0.12) or the group without a migrant background ($T(21)=-1.36$; $p>0.05$; d=0.29).

C. *Analysis by school type*

Looking at the results by type of school, it can be seen that there is a significant change in the results ($T(65)=-2.73$; $p<0.01$) within the group of AI subjects from grammar schools, measured by the mean value of the average score achieved between study day 1 (M1=17.45; SD1=15.76) and study day 2 (M2=22.58; SD2=24.81). Statistical tests confirmed that there was a medium effect (d=0.34) for the improvement in scores using the AI tool. In contrast, no significant change was observed in the control group without AI between the two study days (M1=17.06; SD1=18.21; M2=17.15; SD2=20.01) ($T(71)=-0.05$; $p>.05$, d=0.006). There was also a significant change in scores ($T(71)=-1.88$; $p<0.05$) with a small effect size (d=.22) over the means (M1=3.66; SD1=4.12; M2=5.26; SD2=8.46) within the AI subject group of the secondary school. In contrast, the results of the control group without AI (M1=4.48; SD1=6.04; M2=5.78, SD2=8.96) showed no significant improvement in performance ($T(67)=-1.42$, $p>0.05$).

IV. Discussion

The grammar school students achieved overall scores about three times higher than secondary school students. There were two main reasons for this difference: firstly, the tasks were too challenging, and secondly, there needed to be more standardized mathematical terminology between the two types of schools.

Particularly revealing was the observation that grammar school students who used the AI assistant AIEDN significantly improved their learning performance. In contrast, the control group without AI showed no comparable increase. This suggests that the AI assistant can improve learning performance in grammar schools, helping students master challenging tasks in a more appropriate quantity and quality.

Similar results were observed for the secondary school participants. Although they achieved slightly lower overall scores with AI support than those who did not use AI, there was a significant improvement in learning performance

compared to working on math tasks without AI. This effect did not occur in the non-AI control group. The AI assistant also helped secondary school students to improve their math skills and achieve better overall results.

The difficulties experienced by secondary school students in using the AI assistant could have several causes. The research team was made aware of tasks that were too challenging, which was confirmed by the students' feedback and the results. Daniel Jung's videos were initially designed for high school students and contained different technical terms and topics. However, interviews conducted after the field research showed that secondary school students seek validation in their learning and are more likely to use technology if it is perceived as relevant and exciting. The AI assistant also has the potential to appeal to students with weaker content knowledge if the tasks are adapted to the required performance level.

In summary, both male and female test takers were able to increase their overall scores with the help of the AI assistant, regardless of school type. This suggests a similarly small effect of the AI tool on both genders. In the control groups, however, there was a discrepancy between the overall scores achieved by gender on both days of the study. While the male students, on average, performed worse, the female students were able to achieve a significant increase in learning.

The use of the AI assistant positively impacted the learning performance of migrant students in the grammar school test group. A continuous increase in the total score over both survey periods indicated a medium effect size, and the t-test confirmed the significance of this improvement. In contrast, the control group of grammar school students with a migrant background who did not use the AI assistant showed only a slight, non-significant increase in scores.
The study of non-migrant secondary school students also showed that the AI assistant did not significantly improve performance. Neither the test group with AI nor the control group without AI significantly enhanced learning. In the secondary school study, scores increased minimally in all groups, but there was no significant improvement in the students who used the AI assistant, either with or without a migrant background.

The overall analysis shows that using the AI assistant significantly improved the entire test group, regardless of whether the students had a migrant background. Of particular note, however, is the significant improvement in the grammar school migrant students, which indicates a medium effect size. There were also improvements in performance in the control group without AI assistants, but the students without a migrant background performed significantly better than their classmates with a migrant background. This points to social and educational policy aspects that need further investigation to improve educational equity and equal opportunities in education systems. Therefore, a complete interpretation of these results requires a detailed analysis of the complex interactions between the use of AI-supported learning and students' individual and socio-economic backgrounds.

V. Conclusion

The mixed-methods study aimed to scrutinize three hypotheses on the impact of the AIEDN AI learning assistant on student learning outcomes. The first hypothesis posited that learners utilizing the AI learning assistant would concurrently complete more tasks than those without it. Our findings support this hypothesis, revealing that students, particularly in grammar schools, exhibited significantly improved learning performance when aided by the AI assistant. The results support the second hypothesis that learners using the AI assistant can better understand knowledge and apply it more effectively to transfer tasks. Both grammar and secondary school students demonstrated enhanced learning performance with the AI assistant, positively impacting understanding and application.

The third hypothesis, suggesting that learners engaged with the AI learning assistant would exhibit prolonged retention of acquired knowledge, supports our study. Notably, grammar school students, especially those with a migrant background, consistently increased total scores over both survey periods, indicating a medium effect size regarding knowledge retention.

In summary, the AIEDN AI assistant significantly improved learning performance, particularly among students with high academic achievement.

Consequently, our study provides empirical evidence supporting the positive influence of the AI learning assistant on student learning outcomes across diverse contexts. These findings underscore the potential of AI-supported learning tools to enhance educational experiences, improve performance, and address disparities in learning outcomes.

VI. limitations

In addition to the noteworthy improvements in learning performance and motivation achieved with the AIEDN AI learning assistant, certain constraints and limitations arose during the study. The preliminary survey indicated that most surveyed students mainly engaged in learning activities at home, driven by the conducive low-noise environment. Consequently, the study conducted within a school context was subject to external influences, introducing extraneous variables that could have impacted performance. Factors such as external observation, time constraints, and task volume increased stress, potentially influencing the observed outcomes. Additionally, a notable observation revealed that segments of the secondary school student groups were not consistently active in task engagement during a significant portion of the survey period. This behavior was attributed to feedback from teachers, suggesting that the videos, designed by Daniel Jung, primarily targeted grammar school students, using mathematical terms that were partially incongruent with the teaching concepts and materials in use at secondary schools. Other conceivable variables influencing study outcomes include variations in students' daily form, diverse learning histories, and varying levels of technological affinity.

Moreover, the complexity of the tasks raises considerations regarding evaluating how quickly students solved the tasks on the second study day compared to the initial day. The study did not explicitly assess improvements in specific subject areas, nor did it explore the time allocated

to individual tasks and the potential development of transfer knowledge between tasks, given the flexible, non-consecutive work approach. The absence of a URL blocker or similar tools further limited control over whether students could access the AIEDN prototype on the test device and solve tasks elsewhere. Another factor to account for is the diverse educational systems across individual federal states in Germany. Given the decentralized nature of education governance, variations in curricula and requirements exist. Consequently, the data must be generalized or categorized federally for a comprehensive application of AIEDN in all regions.

Due to its streamlined design, the constraints of the prototype utilized during the study resulted in limited support for adaptive learning. The support extended primarily to visual and auditory modalities through videos facilitated by the learning assistant, excluding learners who rely on text-based materials. This limitation potentially led to stimulus overload, as an excessive number of videos were presented within a specific timeframe, needing a defined threshold for the number of tasks that could be completed.

ACKNOWLEDGMENT

We thank all who contributed to the development of the AIEDN study. First, we would like to thank our cooperation partner - thingsTHINKING GmbH in cooperation with Daniel Jung Media GmbH - for the successful collaboration in our joint research project and the constructive feedback during the development of the AIEDN AI Learning assistant. We would also like to thank the Ministry of Economics, Labour, and Tourism of Baden-Württemberg for their trust and financial support. Furthermore, we would also like to thank our colleagues at the Institute for Applied Research (IAF) and the Institute for Applied Artificial Intelligence (IAAI) at Stuttgart Media University for their advice and support. Special thanks go to all principals, teachers, and participating students at the secondary schools involved in the study and all experts who were available for interviews. We would also like to thank Selina Donat, Carina Simone Weber, Sven Kottmann, Jana Cuntz, Julia Schallmeir, Dominik Maier, Marie-Sophie Michels, Marvin Clauß, Laura Wohnus, Sarah Metzger, and Philipp Dreyer for their active support in carrying out the research and for publicizing our research project.

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