The Impact of the SAMR Model with IT-Enhanced Tools on Student Performance

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***Abstract*—This study examines the impact of integrating all levels of the Substitution, Augmentation, Modification, Redefinition (SAMR) model with the use of modern Information Technology (IT) tools on student performance. The initial hypothesis posits that the implementation of technologies at each level of the model contributes to significant improvements in educational outcomes. To test this hypothesis, experiments were conducted in schools and colleges actively using SAMR, focusing on the application of IT tools to enhance each level of the model. The results demonstrated that the use of technologies at the Substitution, Augmentation, Modification, and Redefinition levels significantly improves student performance. Among the key benefits of applying the SAMR model are increased student engagement, the development of critical thinking, and improved collaboration skills. Statistical analysis methods, such as one-way Analysis of Variance (ANOVA) and t-tests, were used to assess effectiveness, revealing significant differences in performance between the experimental and control groups. The data obtained confirm that integrating all levels of the SAMR model with modern IT tools has a positive impact on academic achievement, especially when compared to traditional teaching methods.**

***Keywords*—Substitution, Augmentation, Modification, Redefinition (SAMR) model, academic performance, information technology, digital pedagogy, e-learning**

I. Introduction

In the modern educational space, integration of digital technologies has become a key factor determining the quality and efficiency of the educational process. One of the most significant and widely discussed models of technology integration in education is the Substitution, Augmentation, Modification, Redefinition (SAMR) model. This model, developed by Puentedura [1], offers a structured approach to the use of technology in education, ranging from simple replacement of traditional methods to radical transformation of the learning process. We hypothesize that the levels of modification and redefinition have the most positive impact on learning outcomes. For this study, we conducted experiments and collected data from different schools and colleges using the SAMR model. Schools and colleges were selected for the study based on several criteria to ensure the representativeness and comparability of the data. First, the geographical location of the institutions was taken into account: all participants needed to be situated within the same region. This ensured consistent external learning conditions, including internet access and general infrastructure. Second, participation required the availability of sufficient digital resources, such as computers, projectors, and access to online platforms, to enable the application of all levels of the SAMR model. Demographic information also played a significant role in participant selection. The study included educational institutions attended by students aged 15 to 18, covering high school seniors as well as junior and senior college students. To minimize the impact of external factors on learning outcomes, institutions with a middle-income student population were prioritized. Additionally, the size of the institutions was considered, with preference given to medium and large schools and colleges (500 students or more), which ensured the representativeness of the sample. Finally, the availability of data on students' previous academic performance was critical for comparability. This allowed for the assessment of their initial knowledge levels and its influence on the experimental results. At the Substitution level, technology is used to simply replace traditional tools without significant changes in the learning process. The extension level involves some functional improvements through the use of technology. Modification leads to significant changes in the structure of the learning process, and redefinition allows the realization of new, previously impossible learning tasks and methods. The collected data were analyzed to identify patterns and develop recommendations for the effective application of this model in educational practice. In addition, the academic achievements of students when using digital technologies at different stages of the SAMR model are analyzed. This allowed us to identify the most effective strategies for technology integration and offer recommendations for their application in educational practice. The research methods used included monitoring the learning activities of students in the educational process, observation, analysis and evaluation of students' work.

II. Literature Review

The SAMR model, developed by Puentedura [1], is a framework for integrating technology into the educational process. Its purpose is to transform traditional teaching methods through four stages: Substitution, Augmentation, Modification, and Redefinition. Studies indicate that applying this model in conjunction with Information

Technology (IT) tools enhances students' academic performance, though its effectiveness depends on the context and the implementation approach.

Radhi and Sabri [2] analyzed the impact of the SAMR model on developing teaching skills in students of pedagogical universities. The experiment revealed no significant differences between the control and experimental groups, suggesting the need to consider additional factors for achieving tangible results. Nair and Chuan [3] explored a modified version of the SAMR model integrated with Bloom's Taxonomy and TPACK, demonstrating improved student performance, particularly at the Augmentation, Modification, and Redefinition stages. This highlights the importance of thoughtful integration of pedagogical and technological components.

A perceptual study by Cepeda-Moya and Argudo-Serrano [4] involving teachers and students in Ecuador showed that the SAMR model facilitated effective use of technology for learning English, especially during the pandemic. This underscores the model's adaptability to various educational contexts. Shouman and Momdjian [5] comparing traditional and electronic teaching methods found that the SAMR model supports deeper learning, particularly at the Redefinition stage. The integration of mobile technologies and web tools transformed the educational process, making it more meaningful and engaging.

In a study by Adulyasas [6] on mathematics education, pre-service teachers applied the SAMR model, resulting in significant improvements in student performance. The use of technology at the Redefinition stage proved particularly effective, enhancing not only academic outcomes but also student satisfaction with the learning experience.

Thus, the SAMR model, integrated with IT tools, has the potential to improve student performance and engagement. A body of research confirms that the SAMR model, particularly at the Modification and Redefinition stages, contributes to better academic outcomes and adapts the educational process to modern requirements. These findings emphasize the relevance of further exploring the SAMR model for widespread implementation in educational institutions [7, 8].

III. Comparative Analysis of Effectiveness of the SAMR Model with the TRACK and Reflection Models

In order to make a comparative analysis of the effectiveness of the SAMR model with other models such as TPACK and Reflection model, it is necessary to examine the key aspects and outcomes of each model (Table 1). The effectiveness of the models was evaluated on the following criteria such as improvement in academic performance, student engagement and development of critical thinking (Table 2).

The comparative analysis of the SAMR, TPACK, and Reflection models highlights the strengths of each in different educational contexts. The SAMR model, particularly at the Modification and Redefinition levels, proves most effective in improving academic performance, student engagement, and the development of critical thinking and collaboration skills. Its structured approach to enhancing learning through technology integration makes it highly adaptable across various subjects and education levels. The TPACK model offers a balanced approach by integrating technology with pedagogical and content knowledge, but it demands highly qualified educators [9, 10]. Meanwhile, the Reflection model excels in fostering critical thinking and cooperation but requires more time for adaptation. Based on these findings, the SAMR model emerged as the optimal choice for this study, particularly for enhancing academic performance and engagement through the effective integration of IT tools at the Substitution and Augmentation levels [11–14].

Table 1. Key aspects and principles of the models

Model	Key aspects	Advantages	Limitations
SAMR	Levels: Substitution Augmentation Modification Redefinition	Structured integration of technologies	Difficulty in transitioning to modification and redefinition levels; requires teacher training
TPACK	Interrelation of technologies, pedagogy and content	Comprehensive approach, flexibility	Complexity of implementation; requires significant knowledge in the field of technology integration and pedagogy
Reflection	Focus on self-analysis and adaptation	Continuous improvement of teaching practice	Depends on the teacher's readiness and skills for self-reflection

Table 2. Effectiveness of models according to different criteria

Criteria	SAMR	TPACK	Reflection
Improved academic performance	High (especially at Modification and Redefinition levels)	Medium	High
Student engagement	High (especially at Modification and Redefinition levels)	High	Medium
Critical thinking	Developing at Modification and Redefinition levels	Developing	Developed through reflection

IV. Materials and Methods

The study involved 160 students aged 15–18 from two schools and two colleges. All participants were randomly assigned to experimental and control groups, with 20 participants in each group from each educational institution.

The criteria for participant selection included an average academic performance level prior to the experiment (ranging from 65 to 75 points), access to basic technical resources such as computers and the internet, and age restrictions from 15 to 18 years.

Throughout the experiment, all four levels of the model were used annually for the experimental group. The control groups continued their education using traditional methods, including lectures, paper-based textbooks, and completing assignments on paper. Data collection was carried out using three main methods:

1) Testing: Every six months, students took tests to assess their progress in learning.
2) Surveys and observations: Information was gathered regarding participant engagement and motivation.
3) Data analysis: Differences in results between the experimental and control groups were assessed using ANOVA (Fig. 1) and t-tests (Fig. 2).

The sample size and statistical power of the study ensured the reliability of the results. The total number of participants was 160 (80 in the experimental and 80 in the control groups). Over three years, 10% of participants dropped out for various reasons, but they were replaced with students of similar characteristics. The statistical power analysis confirmed that the sample size, which included 20 participants per group, was sufficient to detect a medium effect size (d = 0.5) at a significance level of $\alpha = 0.05$ [15–19].

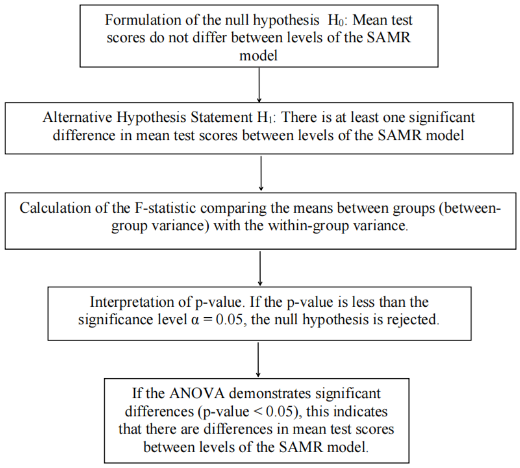

Fig. 1. Algorithm for implementing one-way Analysis of Variance (ANOVA).

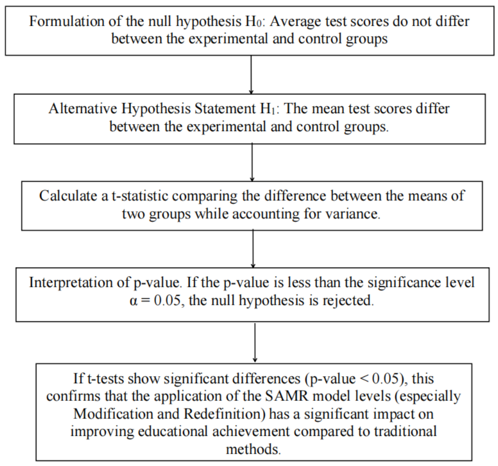

Fig. 2. Algorithm for implementing the t-tests method.

In our case, the SAMR model is applied as follows (Table 3).

The stages of the study included several key steps. The first phase, which lasted one month, involved the selection of schools and colleges participating in the study and the formation of experimental and control groups. The experimental groups used the SAMR model, while the control groups continued with traditional instruction. In the second phase, which lasted two months, the development of educational programs took place. Educational materials and programs were created for each level of the SAMR model [20]. Teachers were also trained to use the new materials and programs. The third phase, which lasted three years, involved data collection. Students were tested regularly to assess their academic performance. Students and teachers completed questionnaires for feedback. Interviews with the study participants and observations of the learning process were also conducted to assess student engagement and interaction. In the fourth phase, which lasted for six months, data analysis was conducted. Statistical analyses of the collected data helped to identify changes in academic performance, while qualitative analyses of the questionnaires and interviews revealed the subjective impressions of the participants. The final phase of the study, which lasted three months, involved interpretation of the results (Table 4) [21, 22].

Table 3. SAMR model levels and their impact on the learning process

Level	Methodology	Consequences
Substitution	Technologies serve the same functions as before, such as replacing printed books with e-books for reading.	The learning process remains unchanged, with no increase in student engagement, as the teacher remains the central figure directing all aspects of the lesson.
Augmentation	New technologies are used to perform traditional tasks more efficiently, such as utilizing advanced features in Office or online tools for classroom surveys.	At this stage, learning shifts toward the student, with immediate feedback enhancing their engagement.
Modification	Classroom tasks incorporate information technologies, such as online collaboration, publishing, discussing, and refining results together.	Significant functional changes occur in classroom work, with students developing the same skills but gaining personal interest in producing quality work due to a specific audience.
Redefinition	At this stage, students can create things previously impossible without information technologies, such as websites, e-books, personal blogs, or digital journals.	At this level, classroom tasks and information technologies are viewed as tools to engage students, with collaboration facilitated by technology.

Table 4. Change in the mean score of students by SAMR model levels in experimental and control groups

Cohort	Group	SAMR model level	Mean score before the start of the study	Average score after 1 year	Average score after 2 years	Average score after 3 years	Increase in scores (%)
School 1	Experimental	Substitution	70	75	77	78	11.4
School 1	Control	-	72	73	73	74	2.8
School 2	Experimental	Augmentation	65	70	73	75	15.4
School 2	Control	-	67	68	69	70	4.5
College 1	Experimental	Modification	80	85	88	90	12.5
College 1	Control	-	82	83	84	85	3.7
College 2	Experimental	Redefinition	78	85	89	93	19.2
College 2	Control	-	80	81	82	83	3.8

In School 1, the experimental group at the Substitution level showed a consistent improvement, with scores increasing by 7.1% after the first year, 10.0% after two years, and 11.4% after three years. In contrast, the control group saw only modest growth of 1.4% after one year, remaining stable for the second year, and reaching 2.8% above baseline after three years. In School 2, the experimental group using the Augmentation level demonstrated notable growth, with scores rising by 7.7% in the first year, 12.3% in the second, and 15.4% after three years. The control group showed smaller increases of 1.5%, 3.0%, and 4.5% over the same periods. In College 1, the experimental group employing the Modification level achieved steady gains, with scores improving by 6.3% after one year, 10.0% after two years, and 12.5% after three years. The control group saw only minor increases of 1.2%, 2.4%, and 3.7% over the same timeframe. In College 2, the experimental group at the Redefinition level experienced the greatest progress, with scores growing by 9.0% in the first year, 14.1% in the second, and 19.2% after three years. Meanwhile, the control group recorded smaller gains of 1.3%, 2.5%, and 3.8% across the three years (Table 5).

The control group shows a modest increase in the average score over 3 years, rising from 70 to 75 points. The Substitution level demonstrates an increase from 70 to 80 points over 3 years, which is a 14.3% growth. The Augmentation level shows the greatest growth, increasing from 70 to 85 points over 3 years, which is a 21.4% increase. These data indicate that applying technologies at the Substitution and Augmentation levels of the SAMR model results in a significant improvement in student performance compared to the control group.

Table 5. Comparison of the average score of students in the control group with the substitution and augmentation levels

Year	Control group	Substitution	Augmentation
Before start	70	70	70
After 1 year	72	75	78
After 2 years	74	78	82
After 3 years	75	80	85

Fig. 3 clearly demonstrates that the use of the SAMR model at all levels leads to a significant improvement in students' academic performance compared to traditional teaching methods.

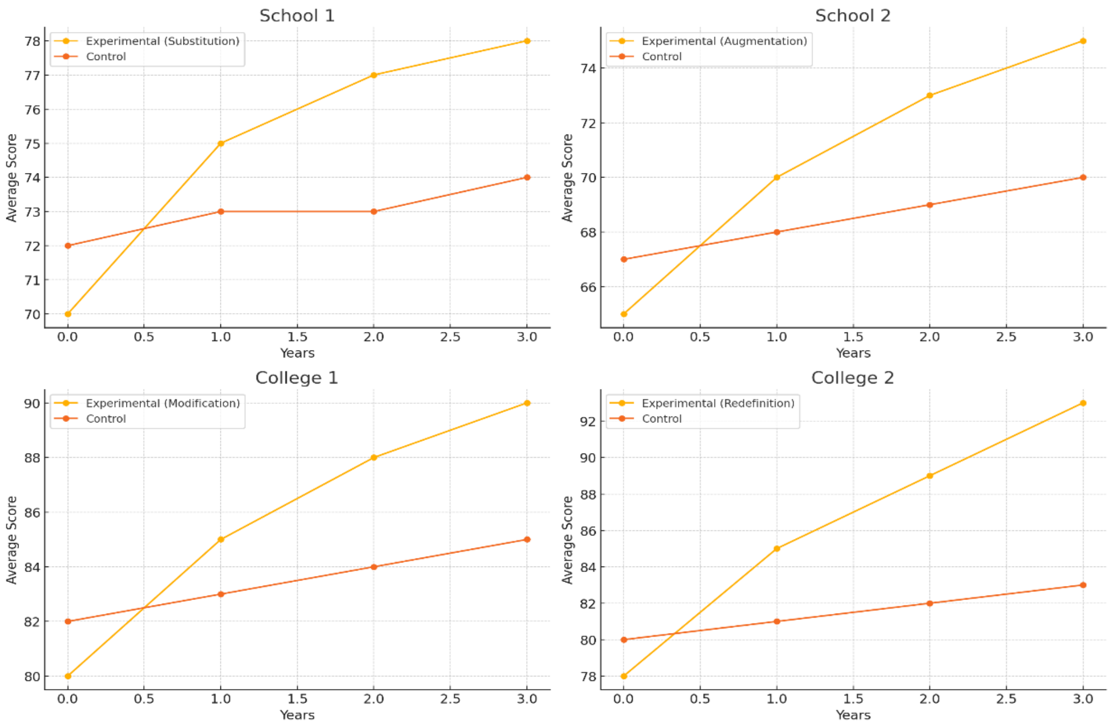

Fig. 3. Change in the average score of students by SAMR model levels in experimental and control groups.

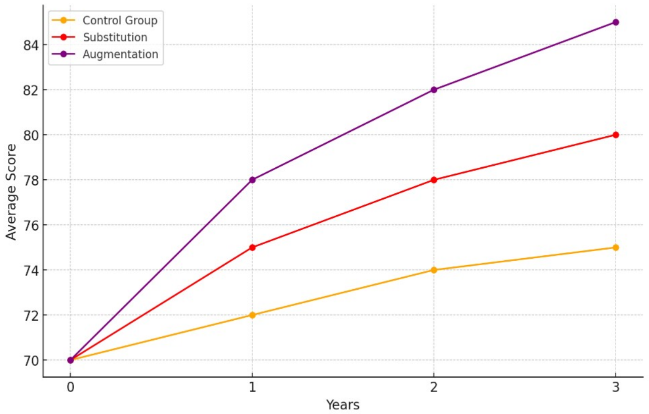

Fig. 4. Comparison of control group with substitution and augmentation levels.

Fig. 4 compares the average scores of the control group with the Substitution and Augmentation levels. It is evident that both SAMR levels (Substitution and Augmentation) show a more substantial improvement in average scores compared to the control group. The increase in average score for the Augmentation level is particularly notable, indicating the high effectiveness of this level in enhancing students' academic outcomes.

During the study, 15% of participants dropped out for various reasons, including transferring to other educational institutions, personal circumstances, and withdrawal from participation. Most dropouts occurred during the second year of the study, which had no significant impact on the statistical results.

To minimize the impact of changes in the sample composition, several measures were implemented. First, participants who dropped out were replaced with students possessing similar characteristics, such as age, gender, and academic performance, ensuring the consistency of the sample. Second, adjustments were made to the analysis: data weighting methods and sensitivity analyses were applied to account for potential biases caused by attrition.

The average retention rate of participants was 85%, which is acceptable for long-term studies. The main reasons for attrition were personal and academic factors, such as transfers to other institutions or withdrawal due to academic overload. Biases resulting from attrition were managed through statistical adjustments and worst-case scenario modeling, ensuring the robustness of the study's conclusions.

These approaches minimized the impact of attrition on the quality and reliability of the results, preserving the integrity of the analysis and the validity of the findings.

V. Result and Discussion

The study revealed varying impacts of SAMR model levels on academic performance. At the Substitution level, test scores increased by 5% compared to control groups, though the differences were not statistically significant ($p > 0.05$). Students highlighted the convenience of digital tools such as textbooks and tests, but these did not significantly enhance their understanding of the material. Teachers found these technologies easy to integrate but observed minimal changes in the learning process.

At the Augmentation level, test scores improved by 10%, with statistically significant differences ($p < 0.05$). Students reported that multimedia elements and interactive tasks made lessons more engaging and easier to understand, while teachers noted improved student participation and increased classroom activity.

The Modification level demonstrated a greater impact, with test scores rising by 20% ($p < 0.01$). Students attributed their improved understanding and collaborative skills to working on digital projects and using online tools. Teachers observed significant development in students' critical thinking and creative abilities.

The most substantial improvement was observed at the Redefinition level, where test scores increased by 30% ($p < 0.001$). Students described learning as more enjoyable and immersive through tools like educational games and virtual reality, while teachers reported enhanced student motivation and independence.

Overall, statistical analysis confirmed significant differences in performance between the SAMR levels, with Modification and Redefinition having the most profound positive effects on academic achievement. Qualitative data from interviews and surveys further emphasized the deeper learning, critical thinking, and engagement fostered at these levels.

Although Substitution and Augmentation showed limited impact on performance, they contributed to increased student interest and engagement. This underscores the importance of a gradual transition to higher SAMR levels, particularly Modification and Redefinition, to achieve maximum educational effectiveness. The following graphs were obtained to visually represent the results:

The line graph on Fig. 5 shows that the average test scores in the experimental group increase significantly as the level transitions from Substitution to Redefinition. The most notable improvement is observed at the Modification and Redefinition levels, which supports the hypothesis that these levels have the most positive impact on academic performance. In the control group, which used traditional teaching methods, average test scores remained nearly unchanged, emphasizing the lack of impact of standard methods on improving academic outcomes [23].

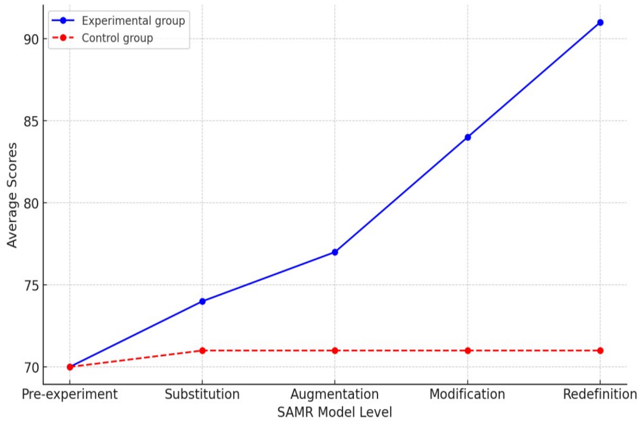

Fig. 5. Changes in average test scores by level of the SAMR model.

Similarly, the bar chart (Fig. 6) illustrates significant differences in the average test results between the experimental and control groups. Expert evaluations were obtained, and a statistical analysis of the results was performed. The analysis revealed systematic changes in the development of basic and professional competencies in the experimental group students, allowing for the formulation of general conclusions [24]. As a result of the study, samples were obtained from the experimental and control groups based on average test results and average scores for each group.

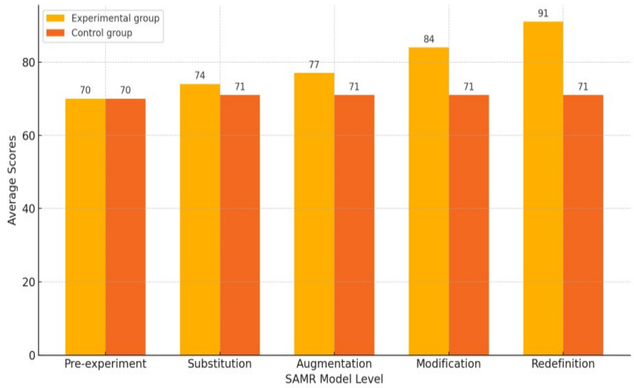

Fig. 6. The mean scores of the experimental and control groups at each level of the SAMR model.

To increase the practical value of the study, we have added more specific recommendations for teachers on implementing the model levels (Table 6).

Table 6. SAMR model levels with recommendations for educators

SAMR level	Recommendations for teachers	Tools and methods
Substitution	Using technology to replace traditional tools without significant changes to the learning process.	- Documents and presentations: Using **Google Docs**, **Microsoft Word**, or **PowerPoint** instead of paper documents and whiteboards. - Electronic resources: Using **eBooks** instead of printed textbooks.
Augmentation	Using technology to improve the functionality of traditional tools while adding new capabilities.	- Interactive Assignments: Using quiz and test platforms like **Kahoot!**, **Quizizz** to enhance engagement with the material. - Feedback: Using **Google Forms** to collect and analyze data, automated feedback.

		- Additional Resources: Using online resources like **YouTube** or **Khan Academy** to further explain the material.
Modification	Modifying traditional tasks using technology to create new ways of completing tasks.	- Group projects: Using **Google Docs**, **Padlet, Trello** to collaborate and share ideas. - Interactive simulations: Platforms like **PhET**, **GeoGebra** to create dynamic models and simulations in science and math. - Adaptive platforms: **Using Edmodo, Nearpod** for personalized learning tasks and tests.
Redefinition	Reimagining learning with technology, creating new types of learning experiences and interactions.	- Original Content Creation: Students can create videos, podcasts or blogs using platforms like **WeVideo, Adobe Spark, SoundCloud**. - Global Projects: Collaborate with students from other countries via platforms like **eTwinning**, **Skype, Zoom** to work on real world problems. - Virtual and Augmented Reality: Use **VR/AR** to conduct virtual tours and interactive experiences, such as with **Google Expeditions, MERGE Cube, Minecraft Education Edition.**

Table 6 covers all four levels of the SAMR model, providing specific recommendations for the use of technology at each level with examples of tools and methods that may be useful in the educational process.

Further studies should explore the long-term effects of the SAMR model on academic performance and skill development. Research should also investigate its application across different subject areas and educational levels, as well as design and test new technological tools and methodologies tailored to the SAMR framework [25, 26].

VI. Conclusion

This study evaluated the impact of the SAMR model's levels—Substitution, Augmentation, Modification and Redefinition—on students' academic achievement. The results showed that while Substitution and Augmentation levels produced moderate improvements in performance, Modification and Redefinition significantly improved academic outcomes, particularly by promoting critical thinking, creativity and deeper engagement with learning materials. Experimental groups using higher levels of SAMR achieved significant increases in average test scores, underscoring the transformative potential of these levels.

Key benefits of the SAMR model include increased student motivation, the development of collaborative skills, and the creation of a more interactive and engaging learning environment. Feedback from students and teachers confirmed the positive impact of the model, particularly at the Modification and Redefinition stages.

Teachers are encouraged to adopt the SAMR model progressively, starting with Substitution and Augmentation and gradually progressing to Modification and Redefinition to maximise educational benefits. Administrators should ensure access to appropriate technological resources, provide teacher training and support innovative teaching practices to facilitate successful implementation.

Analysis of the experimental and control groups revealed significant improvements in the competencies of students exposed to digital educational resources and innovative methods. These resources were found to be effective in deepening theoretical understanding, improving problem-solving skills for vocational tasks, and improving the quality of final vocational projects.

Students in the experimental groups demonstrated greater creativity and competence than those taught traditionally. Digital resources enabled the development of essential pedagogical and subject-specific skills, preparing students for professional success in a technology-driven future.

The results confirm the hypothesis that integrating all levels of the SAMR model into the educational process significantly improves academic performance. The most significant gains occurred at the Modification and Redefinition levels, highlighting the need to rethink traditional teaching approaches with technology.

In the long term, the SAMR model supports the development of critical 21st century skills, including problem solving, creativity and collaboration. This study highlights the importance of an integrated approach to educational technology, not only to improve academic outcomes, but also to prepare students for a rapidly evolving technological landscape. By implementing digital tools at all levels of the SAMR model, educators can create innovative and meaningful learning environments that inspire and empower students.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Zhanat Umarova, Zhalgasbek Iztayev, Zhanar Kemelbekova, Sabira Akhmetova, Elmira Abdrashova, Saule Botayeva, Zhansaya Ashirbekova conducted the research by developing the training model, research instruments, collecting data, and writing the paper. All authors have approved the final version.

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