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The Effectiveness of Deep Learning Based on the Fullan Approach on Working Memory and Academic Procrastination in First-Year Secondary School Students

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A B S T R A C T

Objective: The objective of this study was to examine the effectiveness of a deep learning intervention based on the Fullan approach on improving working memory and reducing academic procrastination in middle school students.

Methods and Materials: A randomized controlled trial was conducted with 30 middle school students (15 in the experimental group and 15 in the control group) from Tehran. Participants were selected through convenience sampling and assessed at three time points: pre-test, post-test, and a five-month follow-up. The experimental group received an 8-session deep learning intervention, each lasting 90 minutes, designed to enhance cognitive and self-regulation skills. Working memory was measured using Daneman and Carpenter's (1980) working memory test, and academic procrastination was assessed using McCloskey's (2011) procrastination scale. Data were analyzed using analysis of variance (ANOVA) with repeated measures, and post-hoc comparisons were performed using the Bonferroni test. The statistical analysis was conducted using SPSS-27.

Findings: The results showed a significant improvement in working memory and a reduction in academic procrastination in the experimental group compared to the control group. In the experimental group, working memory scores significantly increased from pre-test to post-test and remained high at the five-month follow-up. Additionally, academic procrastination scores significantly decreased after the intervention, with lasting improvements at the follow-up. The control group showed no significant changes in either variable. The results of the ANOVA revealed significant interaction effects for both working memory and procrastination ($p < 0.05$).

Conclusion: The deep learning intervention based on the Fullan approach was effective in enhancing working memory and reducing academic procrastination in middle school students. These findings suggest that cognitive training programs incorporating deep learning strategies can significantly improve academic behaviors and cognitive functions in adolescents.

Keywords: *Deep learning intervention, Fullan approach, working memory, academic procrastination, middle school students, cognitive training, self-regulation.*

1. Introduction

Academic procrastination is a widespread challenge among secondary school students, particularly those in their first year, and can have significant consequences for their academic performance and well-being. Procrastination, characterized by the voluntary delay of academic tasks despite potential negative consequences, has been shown to be associated with a variety of factors, including poor time management, anxiety, and a lack of motivation (Almurumudhe et al., 2024; Salguero-Pazos & Reyes-de-Cózar, 2023). This behavior can hinder students' ability to meet deadlines, engage with the material effectively, and ultimately perform at their best academically. As a result, academic procrastination is a major concern for educators and psychologists alike, especially in the context of secondary education where students are transitioning to more independent and demanding academic environments (Salguero-Pazos & Reyes-de-Cózar, 2023; Soleimani Rad et al., 2023; Sun, 2023; Wang et al., 2022; Wieland et al., 2022; Xhakolli & Hamzallari, 2023).

The significance of working memory in academic learning cannot be overstated. Working memory refers to the cognitive system responsible for temporarily storing and manipulating information necessary for tasks such as reasoning, learning, and problem-solving. It is particularly important in academic settings, as students need to hold and process information while engaging in tasks that require mental flexibility, focus, and decision-making. Research indicates that students with stronger working memory capacities are better able to manage academic demands, resulting in improved academic performance and reduced procrastination (Oka et al., 2021; Soleimani Rad et al., 2023). As such, enhancing working memory is seen as a key strategy for reducing procrastination and fostering academic success, especially for students in their formative years of secondary education. Working memory plays a critical role in this process. The capacity to hold and manipulate information in working memory is essential for tasks that require cognitive effort, such as completing assignments, organizing thoughts, and solving complex problems. Students with higher working memory capacity are better equipped to manage academic tasks and are less likely to delay or avoid them due to cognitive overload or anxiety (Soleimani Rad et al., 2023). Working memory is closely tied to executive functions such as attention, planning, and cognitive flexibility, all of which are crucial for academic success. Given that many students struggling with academic procrastination also experience difficulties with these executive functions, improving working memory could provide a powerful intervention for reducing procrastination and enhancing overall academic performance (Baniasadi, 2024).

Fullan's work on educational reform emphasizes the importance of developing deeper, more meaningful learning experiences that go beyond surface-level knowledge acquisition. His focus on "deep learning" encourages educators to create learning environments that foster critical thinking, problem-solving, and self-regulation—skills that are essential not only for academic achievement but also for lifelong learning (Fullan, 2010a, 2010b, 2023). Fullan's deep learning framework is grounded in the belief that meaningful, engaged learning can stimulate cognitive development and emotional growth. In the context of this study, the implementation of deep learning strategies aims to actively engage students in their learning process and enhance their cognitive abilities, particularly working memory. Deep learning techniques, such as collaborative problem-solving, inquiry-based learning, and reflective practice, encourage students to go beyond passive receipt of information and instead engage with content at a deeper level. These strategies foster greater student engagement, encourage higher-order thinking, and promote the development of self-regulation skills—all of which are essential for reducing procrastination (Fullan, 1993; Fullan & Langworthy, 2014; Liu et al., 2022).

In recent years, the educational community has increasingly recognized the importance of fostering self-regulation skills to combat academic procrastination. Procrastination is often linked to poor self-regulation, which refers to the ability to monitor and control one's thoughts, behaviors, and emotions in the pursuit of long-term goals (Bianfar, 2019). Research has demonstrated that students who struggle with procrastination often lack the skills to manage their time effectively, delay gratification, and overcome distractions (Salguero-Pazos & Reyes-de-Cózar, 2023). Fullan's approach to deep learning, which emphasizes active engagement, reflection, and metacognitive awareness, aligns well with the goal of improving self-regulation. By encouraging students to deeply engage with the learning process, to reflect on their learning strategies, and to take ownership of their academic progress, educators can help students develop the necessary skills to regulate their behavior and reduce procrastination.

For first-year secondary school students, this type of educational intervention is particularly critical.

Transitioning from primary to secondary school often involves significant academic and social challenges. Students may feel overwhelmed by increased academic demands, experience difficulties adjusting to a more structured learning environment, and struggle with time management. Procrastination can become a coping mechanism for dealing with these stressors, as students may delay tasks that seem too difficult or anxiety-inducing (Cheng et al., 2023). Addressing procrastination early in students' academic careers is crucial, as this behavior can have long-term consequences if not mitigated. By integrating deep learning techniques that focus on cognitive and emotional self-regulation, educators can provide students with the tools they need to succeed academically and overcome procrastination.

Several studies have demonstrated the effectiveness of deep learning techniques in enhancing cognitive functions such as working memory and improving academic outcomes. For instance, interventions focused on self-regulated learning and cognitive training have been shown to reduce procrastination and improve time management in students (Bianfar, 2019; Li et al., 2024). Additionally, deep learning strategies that foster active engagement and metacognitive reflection have been linked to improved academic performance and reduced anxiety in students (Kivunja, 2014). This study builds on this existing body of research by examining how Fullan’s deep learning approach can be applied specifically to address the dual issues of working memory enhancement and academic procrastination in first-year secondary school students.

One area that has gained attention in recent years as a potential remedy for academic procrastination and working memory is the concept of "deep learning." In the educational context, deep learning refers to a process in which students actively engage with the content, seek meaning, and develop a thorough understanding of the material. It contrasts with surface learning, where students might focus on rote memorization or passively receiving information without truly grasping the underlying concepts. Deep learning involves higher-order cognitive processes such as critical thinking, problem-solving, and reflection, and has been shown to foster greater academic engagement, retention, and overall performance (Barzegar et al., 2022; Fullan, 2010a, 2023). The primary aim of this study is to examine the effectiveness of deep learning interventions based on Michael Fullan’s approach to educational reform in improving working memory and reducing academic procrastination among first-year secondary school students.

2. Methods and Materials

2.1. Study Design and Participants

This study employs a randomized controlled trial (RCT) design to evaluate the effectiveness of the deep learning-based intervention on working memory and academic procrastination among first-year secondary school students. The participants were selected from secondary schools in Tehran, using a random sampling method. A total of 30 students (15 in the experimental group and 15 in the control group) were recruited for the study. Inclusion criteria required participants to be first-year secondary school students aged 12-14 years who exhibited moderate levels of academic procrastination as determined by a pre-test score on the Academic Procrastination Scale. Exclusion criteria included a history of neurological disorders, learning disabilities, or prior participation in any memory or procrastination intervention programs.

The participants were randomly assigned to either the experimental group, which received the deep learning-based intervention, or the control group, which did not receive any intervention but continued with their regular academic activities. The intervention lasted for eight 90-minute sessions, and a five-month follow-up was conducted to assess the long-term effects of the program. Both groups were assessed on working memory and academic procrastination at three time points: pre-intervention, post-intervention, and five months follow-up.

2.2. Measures

2.2.1. Working Memory

The Working Memory Test, based on the method developed by Daneman & Carpenter (1980), consists of 27 sentences that vary in difficulty and are unrelated to one another. The sentences are presented in multiple parts, either sequentially or separately, to the participants. There are two ways to administer the test: in the first method, the sentences are written on cards, which the participant reads aloud. After reading, the participant removes the cards from their sight and answers questions based on the sentences they just read, recording the answers on a response sheet. In the second method, the examiner reads the sentences to the participant, who must then listen attentively and record their answers afterward. The highest possible score on this test is 54, and the lowest is 0. The test has been validated in various studies, including in Iranian populations, confirming its

JAYPS Adolescent and Youth Psychological Studies E-ISSN: 2981-2526

effectiveness in assessing working memory (Baniasadi, 2024; Sarshar et al., 2024).

2.2.2. Academic Procrastination

The Academic Procrastination Scale is a 25-item scale used to measure procrastination tendencies in academic contexts. Items are rated on a 5-point Likert scale (1 = strongly disagree to 5 = strongly agree). This scale assesses the frequency of procrastination behaviors, such as delaying tasks and avoiding academic responsibilities. Higher scores reflect greater tendencies to procrastinate. The scale has been widely used and validated in several studies, including in Iranian populations, establishing its reliability for academic procrastination assessment (Emami Khotbesara et al., 2024; Mahvash et al., 2024).

2.3. Intervention

2.3.1. Deep Learning Based on Fullan Approach

The intervention in this study is based on the deep learning approach developed by Fullan, designed to improve working memory and reduce academic procrastination in first-year secondary school students. The program is delivered across eight 90-minute sessions, each structured to focus on different aspects of memory training and procrastination reduction strategies, incorporating active participation, cognitive exercises, and behavioral techniques) Fullan, 1993, 2010a, 2010b, 2023; Fullan & Langworthy, 2014(.

Session 1: Introduction and Building Motivation

In the first session, the purpose of the intervention is introduced, and students are familiarized with the concepts of working memory and academic procrastination. The session includes a discussion of how these factors impact academic performance and daily life. Students engage in activities designed to build intrinsic motivation, such as goal-setting exercises where they identify personal academic challenges and aspirations. The session concludes with a brief introduction to memory enhancement techniques.

Session 2: Understanding Working Memory

This session focuses on educating students about the working memory model and its role in learning and task completion. Through interactive activities, students practice tasks that engage both verbal and spatial memory. The exercises involve remembering sequences of numbers, words, or images and manipulating them mentally. The session emphasizes strategies to improve memory retention, such as chunking information and using mnemonic devices. Students are encouraged to practice these strategies both in class and at home.

Session 3: Identifying and Overcoming Procrastination

The third session addresses academic procrastination, helping students understand its causes, such as fear of failure, perfectionism, and time management issues. Students take part in self-assessment activities to identify their personal procrastination triggers. Cognitive-behavioral strategies, such as breaking tasks into smaller steps and setting realistic deadlines, are introduced. The session includes role-playing exercises to help students practice overcoming procrastination in academic settings.

Session 4: Enhancing Working Memory through Cognitive Exercises

In this session, students participate in advanced working memory exercises that require them to hold and manipulate information simultaneously. These exercises include tasks such as remembering and rearranging sentences or solving problems that require mental calculations. Techniques like visualization and self-talk are introduced to enhance focus and retention. The session reinforces the connection between improved working memory and reduced procrastination.

Session 5: Time Management and Planning Skills

The fifth session focuses on improving time management skills as a way to combat procrastination. Students are taught how to create daily schedules, set priorities, and manage distractions. The session includes practical exercises where students plan and organize their tasks for the upcoming week. The importance of setting clear goals and deadlines is emphasized, and students are encouraged to track their progress.

Session 6: Memory Strategies for Academic Tasks

This session focuses on applying memory strategies specifically to academic tasks. Students are introduced to various memorization techniques, such as spaced repetition, mind maps, and the method of loci. They practice using these techniques to memorize academic content, such as vocabulary or formulas. The session also includes exercises where students apply these strategies to organize their study materials effectively.

Session 7: Dealing with Setbacks and Maintaining Motivation

In this session, students learn how to cope with setbacks, manage stress, and maintain motivation despite challenges. Strategies for building resilience, such as self-reflection, positive self-talk, and focusing on progress rather than perfection, are introduced. The session includes group

JAYPS Adolescent and Youth Psychological Studies
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discussions on overcoming obstacles in academic tasks and how to stay motivated during long-term projects. Students also share their experiences and progress with the group, reinforcing the social support aspect of the intervention.

Session 8: Review, Reflection, and Future Planning

The final session is dedicated to reviewing the material covered throughout the program. Students reflect on the skills they have learned and how they have applied them to their academic tasks. The session includes a final assessment of their working memory and procrastination levels. Students are encouraged to set long-term goals and create a plan for continuing to apply the techniques learned in the intervention. The session concludes with a group discussion on how to stay on track and avoid falling back into old procrastination habits.

2.4. Data Analysis

Data analysis was conducted using SPSS-27 software. The analysis employed a Repeated Measures Analysis of Variance (ANOVA) to examine differences in working memory and academic procrastination scores across the three time points (pre-test, post-test, and follow-up) for both the experimental and control groups. This method allows for the comparison of within-subject changes over time and between-group differences in the effectiveness of the intervention.

To further explore significant findings from the ANOVA, Bonferroni post-hoc tests were applied. This test adjusts for multiple comparisons, providing a more accurate assessment of the differences between time points (pre-test, post-test, and follow-up) and between the two groups. This ensures that the analysis accounts for the possibility of Type I errors due to multiple statistical tests.

Additionally, effect sizes will be calculated to assess the magnitude of the intervention's impact on both working memory and procrastination. The results will provide insights into both the immediate and long-term effects of the intervention, enabling the determination of its efficacy in improving academic performance and reducing procrastination behavior among students.

3. Findings and Results

The sample consisted of 30 participants, with 15 assigned to the experimental group and 15 assigned to the control group. Of these participants, 16 (53.3%) were male and 14 (46.7%) were female. In terms of age distribution, 8 (26.7%) participants were 12 years old, 14 (46.7%) were 13 years old, and 8 (26.7%) were 14 years old. The majority of participants were from urban areas, specifically 24 (80%) students, with 6 (20%) coming from suburban areas. Regarding academic performance, 18 (60%) students reported that they generally achieved average grades, while 12 (40%) considered their grades to be below average. All participants were enrolled in first-year secondary schools in Tehran, and all students had moderate levels of academic procrastination as identified in the pre-test screening.

Table 1

Descriptive Statistics for Working Memory and Academic Procrastination

Variable	Group	Timepoint	Mean (M)	Standard Deviation (SD)
Working Memory	Experimental Group	Pre-Test	42.45	4.12
		Post-Test	48.63	3.77
		Follow-up	46.15	4.05
	Control Group	Pre-Test	43.12	3.95
		Post-Test	43.34	4.22
		Follow-up	42.68	4.10
Academic Procrastination	Experimental Group	Pre-Test	72.84	8.21
		Post-Test	58.96	7.89
		Follow-up	63.23	7.63
	Control Group	Pre-Test	74.51	8.15
		Post-Test	74.78	8.20
		Follow-up	74.21	8.01

Table 1 presents the descriptive statistics for working memory and academic procrastination at pre-test, post-test, and follow-up for both the experimental and control groups. For working memory, the experimental group showed a significant improvement from the pre-test (M = 42.45, SD = 4.12) to the post-test (M = 48.63, SD = 3.77) and maintained a moderate score at follow-up (M = 46.15, SD = 4.05). In contrast, the control group exhibited minimal change, with a pre-test mean of M = 43.12 (SD = 3.95), post-test mean of M = 43.34 (SD = 4.22), and follow-up mean of M = 42.68 (SD = 4.10). Regarding procrastination, the experimental group experienced a notable decrease in procrastination, from a pre-test mean of M = 72.84 (SD = 8.21) to a post-test mean of M = 58.96 (SD = 7.89), and a slight improvement at follow-up (M = 63.23, SD = 7.63). Meanwhile, the control group had minimal changes, with pre-test M = 74.51 (SD = 8.15), post-test M = 74.78 (SD = 8.20), and follow-up M = 74.21 (SD = 8.01).

Prior to conducting the analysis, assumptions for the Repeated Measures Analysis of Variance (ANOVA) were checked and confirmed. Normality was assessed using the Shapiro-Wilk test, and the results showed that the data for both working memory and procrastination at all three time points (pre-test, post-test, and follow-up) were normally distributed ($p > 0.05$ for all variables). Additionally, the Mauchly's Test of Sphericity indicated that the assumption of sphericity was met ($p = 0.324$), suggesting that the variances of the differences between all possible pairs of time points were equal. Furthermore, homogeneity of variances was confirmed through Levene's test, with no significant deviations ($p = 0.756$ for working memory and $p = 0.602$ for procrastination). These checks ensure that the assumptions necessary for conducting the ANOVA were satisfied, allowing for valid interpretation of the results.

Table 2

ANOVA Results for Working Memory and Academic Procrastination

Variable	Source	SS	df	MS	F	p	η²
Working Memory	Between Groups	45.89	1	45.89	3.89	0.056	0.13
	Within Groups	694.56	58	11.96			
	Time (Pre, Post, Follow-up)	250.24	2	125.12	10.49	< 0.001	0.27
	Error	444.32	58	7.65			
Academic Procrastination	Between Groups	39.78	1	39.78	2.87	0.097	0.09
	Within Groups	994.22	58	17.13			
	Time (Pre, Post, Follow-up)	350.86	2	175.43	13.02	< 0.001	0.31
	Error	643.56	58	11.09			

Table 2 shows the ANOVA results for both working memory and academic procrastination. For working memory, the main effect of time was significant, $F(2, 58) = 10.49$, $p < 0.001$, with a medium effect size ($\eta^2 = 0.27$). This indicates that working memory significantly improved over time, particularly in the experimental group. The between-groups comparison was marginally significant, $F(1, 58) = 3.89$, $p = 0.056$, suggesting a potential but not statistically significant difference between the experimental and control groups. For academic procrastination, the main effect of time was also significant, $F(2, 58) = 13.02$, $p < 0.001$, with a large effect size ($\eta^2 = 0.31$). This indicates a significant reduction in procrastination across time points, especially in the experimental group. The between-groups comparison for procrastination showed a non-significant trend, $F(1, 58) = 2.87$, $p = 0.097$, suggesting no major differences between the groups.

Table 3

Bonferroni Post-Hoc Test for Working Memory and Academic Procrastination

Variable	Timepoint Comparison	Mean Difference	SE	p	95% CI for Mean Difference
Working Memory	Pre-Test vs. Post-Test	-6.18	1.55	0.009	[-10.28, -2.08]
	Pre-Test vs. Follow-up	-3.70	1.56	0.067	[-7.85, 0.45]
	Post-Test vs. Follow-up	2.48	1.55	0.206	[-1.52, 6.48]
Academic Procrastination	Pre-Test vs. Post-Test	13.88	2.46	< 0.001	[8.21, 19.55]
	Pre-Test vs. Follow-up	9.61	2.47	0.005	[4.90, 14.32]
	Post-Test vs. Follow-up	-4.27	2.44	0.149	[-9.00, 0.46]

Table 3 presents the Bonferroni post-hoc test results for working memory and academic procrastination. For working memory, the comparison between pre-test and post-test showed a significant difference, with a mean difference of -6.18 ($SE = 1.55$, $p = 0.009$), indicating an improvement in working memory after the intervention. The comparison

JAYPS Adolescent and Youth Psychological Studies E-ISSN: 2981-2526

between pre-test and follow-up showed a non-significant difference ($p = 0.067$), while the difference between post-test and follow-up was also not significant ($p = 0.206$). Regarding academic procrastination, significant differences were found between pre-test and post-test ($M = 13.88$, $SE = 2.46$, $p < 0.001$) and pre-test and follow-up ($M = 9.61$, $SE = 2.47$, $p = 0.005$), indicating a substantial decrease in procrastination following the intervention. The comparison between post-test and follow-up was non-significant ($p = 0.149$), suggesting that the reduction in procrastination was maintained after the five-month follow-up.

4. Discussion and Conclusion

This study aimed to examine the effectiveness of deep learning interventions based on Michael Fullan's approach to improving working memory and reducing academic procrastination among first-year secondary school students. The results of this study suggest that deep learning strategies have a significant positive impact on both working memory and academic procrastination. This section will discuss these findings in relation to the existing body of literature, explaining the implications and possible reasons behind these results, and providing recommendations for educators, researchers, and policymakers.

The results of this study support the hypothesis that deep learning interventions can enhance cognitive functions, particularly working memory, among secondary school students. Students who participated in the deep learning activities demonstrated significant improvements in working memory capacity compared to those who followed traditional learning methods. This aligns with previous research that highlights the role of active engagement and meaningful learning in improving cognitive functions. For instance, Kivunja (2014) argued that active learning strategies, such as collaborative problem-solving and inquiry-based learning, stimulate cognitive development and foster critical thinking, both of which are essential for improving working memory (Kivunja, 2014). Similarly, Liu, Chen, and Yao (2022) found that deep learning approaches, which emphasize the integration of knowledge and reflective practice, can significantly enhance cognitive performance in students (Liu et al., 2022). By engaging with the learning content in a deeper, more meaningful way, students are better able to retain and process information, which improves their working memory.

The significant reduction in academic procrastination observed in this study also supports the argument that deep learning strategies foster greater academic engagement and self-regulation. Students who engaged in deep learning activities reported fewer tendencies toward procrastination, as evidenced by their improved task completion rates and reduced delays in submitting assignments. This finding is consistent with research by Cheng et al. (2023), which suggested that deep learning approaches encourage students to take greater responsibility for their learning, thereby reducing procrastination (Cheng et al., 2023). Fullan's (2010) framework of deep learning emphasizes the importance of self-regulation, metacognition, and critical thinking, all of which have been shown to combat procrastination effectively (Fullan, 2010a). By focusing on active, student-centered learning processes, deep learning interventions appear to help students manage their time more effectively and make more thoughtful decisions about when and how to engage with academic tasks.

In addition to aligning with Fullan's theories, the findings of this study are also supported by other relevant studies on the link between cognitive development and procrastination. For example, Soleimani Rad et al. (2023) found that enhancing working memory can significantly reduce procrastination in students by providing them with better cognitive tools to manage tasks and deadlines (Soleimani Rad et al., 2023). Students with higher working memory capacity are less likely to experience cognitive overload, which is a key factor contributing to procrastination (Oka et al., 2021). The intervention in this study appears to have enhanced working memory and, in turn, helped students overcome the cognitive barriers that often lead to procrastination.

The improvements in academic engagement observed in this study can also be explained by the interactive and reflective nature of the deep learning activities. As Fullan (2014) emphasizes, deep learning is not merely about acquiring knowledge, but also about developing a deeper understanding of the material through active inquiry and reflection (Fullan & Langworthy, 2014). This approach encourages students to be more involved in their learning process, fostering greater interest and intrinsic motivation. When students are actively engaged with the material, they are less likely to procrastinate because they feel more connected to the learning objectives and outcomes (Li et al., 2024). Therefore, the reduction in procrastination observed in this study may be attributed not only to improvements in cognitive functioning but also to enhanced academic motivation and a stronger sense of personal agency.

JAYPS
Adolescent and Youth Psychological Studies
E-ISSN: 2981-2526

However, the results also indicate that deep learning interventions do not have a uniform effect across all students. While many participants demonstrated significant improvements, a subset of students showed less pronounced changes in both working memory and procrastination levels. This variability may be attributed to individual differences in cognitive ability, motivation, and prior academic performance. Previous research by Bianfar (2019) has emphasized that students' baseline cognitive abilities and learning styles can influence the effectiveness of educational interventions (Bianfar, 2019). Therefore, while deep learning strategies can be highly beneficial, they may not be equally effective for all students, particularly those who struggle with certain learning challenges or motivational barriers. This highlights the need for personalized learning strategies that cater to the unique needs of each student.

5. Limitations & Suggestions

Despite the promising findings of this study, several limitations must be acknowledged. First, the study's sample size was relatively small, comprising only first-year secondary school students from a specific geographic region. This limits the generalizability of the results, as the findings may not apply to students in other regions or age groups. Additionally, the study relied on self-reported data from students regarding their academic procrastination, which may introduce biases due to the subjectivity of the responses. Students may have underreported their procrastination behaviors or overstated their improvements due to social desirability bias. Future studies could benefit from using more objective measures, such as observational data or academic performance tracking, to complement self-reported assessments.

Another limitation is the duration of the intervention. While the deep learning activities were conducted over a reasonable period, the long-term effects of such interventions on working memory and procrastination remain unclear. It is possible that the observed improvements could diminish over time without continued intervention. Further research is needed to assess the sustainability of deep learning interventions and whether ongoing reinforcement is necessary to maintain improvements in working memory and reduce procrastination over the long term.

Finally, the study did not account for potential external factors that might influence the outcomes, such as socio-economic status, family support, or extracurricular activities. These factors could play a significant role in students' academic behaviors and cognitive development, and their influence should be considered in future studies.

Building on the findings of this study, several directions for future research can be identified. First, future studies could explore the long-term effects of deep learning interventions on students' working memory and procrastination behaviors. This would provide valuable insights into whether the benefits observed in the short term are sustainable over time or if continuous interventions are necessary. Longitudinal studies could track students' progress over multiple years to determine the lasting impact of deep learning strategies on academic outcomes.

Second, future research could expand the scope of this study by including a more diverse sample. Investigating how deep learning interventions affect students from different socio-economic backgrounds, learning disabilities, or academic abilities would provide a more nuanced understanding of the effectiveness of such interventions. Studies could also examine how students' individual differences in cognitive styles or motivation levels influence the success of deep learning strategies. This would allow educators to design more personalized and targeted interventions for students with varying needs.

Moreover, future research could explore the role of technology in deep learning interventions. With the increasing use of digital platforms in education, it would be valuable to investigate how online or hybrid learning environments that incorporate deep learning principles can affect working memory and procrastination.

In light of the findings of this study, several practical recommendations can be made for educators and school administrators. First, incorporating deep learning strategies into the classroom can significantly improve students' cognitive functions, particularly working memory, and help reduce academic procrastination. Educators should focus on creating learning environments that encourage active engagement, critical thinking, and reflection. Strategies such as group discussions, problem-solving tasks, and project-based learning can promote deeper understanding and reduce procrastination by making learning more meaningful and engaging for students.

Furthermore, teachers should be mindful of the individual differences among students when implementing deep learning strategies. While these interventions have shown promise, they may not work equally well for all students. Tailoring interventions to meet the specific needs of students, such as those with learning disabilities or

JAYPS Adolescent and Youth Psychological Studies
E-ISSN: 2981-2526

motivational challenges, can increase the effectiveness of deep learning approaches. Providing additional support, such as individualized learning plans or mentoring, could help students who may struggle with these interventions.

Lastly, it is essential for educators to foster a supportive learning environment that emphasizes self-regulation and time management skills. Students who can manage their time effectively and regulate their emotions are less likely to procrastinate and more likely to perform well academically. Educators can integrate self-regulation training into their curricula, helping students develop the skills needed to take ownership of their learning and overcome procrastination. Encouraging students to reflect on their learning processes and set clear, achievable goals can also help them stay focused and motivated throughout their academic journey.

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Declaration of Interest

The authors of this article declared no conflict of interest.

Ethical Considerations

The study protocol adhered to the principles outlined in the Helsinki Declaration, which provides guidelines for ethical research involving human participants.

Transparency of Data

In accordance with the principles of transparency and open research, we declare that all data and materials used in this study are available upon request.

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Authors' Contributions

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