Original scientific paper

Received: January 15, 2025.
Revised: March 16, 2025.
Accepted: March 20, 2025.

UDC:
159.922.82.072
37.091.31-'59.1/.2
10.23947/2334-8496-2025-13-1-1-13

Check for updates

Improving the Cognitive Flexibility (CF) of Adolescent Students Through Differentiated Instructions in Indonesia

Zulmi Ramdani[1*], *Deni Hadiana*[2], *Misbah Fikrianto*[3], *Novi Sylvia*[2], *Nur Alia*[2], *Andi Amri*[4], *Handan Can*[5]

[1]Institute of Social Science, Bursa Uludağ Üniversitesi, Bursa, Turkiye; Faculty of Psychology UIN Sunan Gunung Djati Bandung, Bandung, Indonesia, e-mail: 712345006@ogr.uludag.edu.tr
[2]Pusat Riset Pendidikan, Badan Riset dan Inovasi Nasional (BRIN), Jakarta, Indonesia, e-mail: deni.hadiana@brin.go.id, novi.sylvia@brin.go.id; nura027@brin.go.id,
[3]Fakultas Keguruan dan Ilmu Pendidikan Universitas Islam Asy-Syafi'iyah, Bekasi, Indonesia, e-mail: misbah.fkip@uia.ac.id
[4]Department of Islamic Banking, Universitas Muhammadiyah PROF DR Hamka, Jakarta, Indonesia, e-mail: andiamri@uhamka.ac.id
[5]Department of Psychology, Bursa Uludağ Üniversitesi, Bursa, Turkiye, e-mail: handancan@uludag.edu.tr

Abstract: Students are expected to be adequately prepared to respond to technological advancements and complex global challenges. In this context, cognitive flexibility plays a crucial role in facilitating the development of appropriate alternative strategies. Previous research has identified several relevant learning activities aimed at enhancing cognitive flexibility. In the context of differentiated instruction, cognitive flexibility is further elaborated through consideration of the individual uniqueness of students, the learning situation, and the environment, making this concept particularly relevant to the educational setting in Indonesia. Consequently, this study aimed to enhance the cognitive flexibility of adolescent students through differentiated instruction training. A total of 70 adolescent students participated in a one-group pretest-posttest experimental design using convenience sampling. The participants completed an informed consent form and engaged in training activities for approximately 4 weeks. The findings indicated that 66% of participants showed an increase in cognitive flexibility attitudes following the learning intervention. Furthermore, inferential statistical analysis revealed significant differences between pretest and posttest results. The differentiated instruction training proved effective in improving cognitive flexibility attitudes. This research has implications for the development of effective learning models and provides recommendations for the enhancement of skills among adolescent students, not only within the context of Indonesia but also for potential implementation in different cultures and locations.

Keywords: *adolescent, cognitive flexibility, differentiated instruction, students' diversity.*

Introduction

The complexity of learning is subjecting individuals to increasingly challenging conditions. In this context, the rapid advancement of technology with diverse global demands has intensified the complexity of learning (Amir et al., 2020; Dargan et al., 2020; Oke and Fernandes, 2020). Even though learning was conducted through a face-to-face classroom system, the concept has evolved into an open and distance model. The presence of teachers has innovated through the many sources of contemporary and limitless learning. The changes should be anticipated adaptively, solution-oriented, and sustainable to obtain optimal learning outcomes. Therefore, a strong positive character and skills relevant to the various complexities must be shown (Ramdani et al., 2024; Zuhdiyah et al., 2024). One of them is cognitive flexibility skills which are important for individuals to deal with various situations.

Cognitive flexibility increases the ability to adapt to existing complexities (Leimar et al., 2024). This also improves performance in tasks that require adaptation to new rules or conditions (Tello-Ramos et al., 2019). Recent research explained that cognitive flexibility was an important characteristic, specifically for

*Corresponding author: 712345006@ogr.uludag.edu.tr

students in carrying out the learning process (Ionescu, 2012; Richard's et al., 2021). Cognitive flexibility plays a role in directing, establishing, and providing problem-solving strategies (Braem and Egner, 2018). The variable describes the behavior of an individual and is directly related to the level of intelligence (Ionescu, 2012). However, it can be trained, developed, and optimized through a series of activities connected to learning principles (Braem and Egner, 2018).

In several scientific research, cognitive flexibility was analyzed from various perspectives. From a psychological perspective, cognitive flexibility is a positive character obtained from a continuous learning process accompanied by reinforcement from the environment an individual grows and develops (Dennis and Vander Wal, 2010; Ionescu, 2012). Cognitive flexibility is based on basic associative learning mechanisms conditioned by simple incentives and influenced by bottom-up contextual cues, including subliminal cues (Braem and Egner, 2018). From a medical and neuroscience perspective, cognitive flexibility is acquired due to genetic results, innate intelligence, and optimal function in the brain (Dajani and Uddin, 2015; Kehagia et al., 2010; Masley et al., 2009). Additionally, it is supported by a distributed network through the integration of the frontal, temporal, and parietal lobes in the brain (Dajani et al., 2020; Uddin, 2021).

Cognitive flexibility is seen as an important skill for individuals to survive in the complexities of life to achieve optimal learning (Dajani and Uddin, 2015; Ionescu, 2012). Several researchers have tried to find strategies used to improve the concept. From a health perspective, cognitive flexibility can be improved through aerobic activity (Masley et al., 2009), fitness, and monitoring (Themanson et al., 2008), as well as dancing activities (Coubard, 2011). This has been shown to support daily life functions such as reducing symptoms of depression and eating disorders (Duriez et al., 2021). In social science, specifically education, many learning methods can be used to improve skills, such as metacognitive training (Buttelmann and Karbach, 2017), reasoning training (Scheibling-Sève et al., 2022), as well as technology-based learning activity and innovation (Wang and Jou, 2023). This research has succeeded in increasing the cognitive flexibility of participants in the implementation.

Intervention through training programs can significantly increase individual cognitive flexibility. The training has a direct effect since the goals to be achieved must be specific (Van Bers et al., 2020). In addition, the development can vary across different cultural contexts. Hence, curriculum design needs to consider individual experiences (Legare et al., 2018). In the Indonesian context, cognitive flexibility is very important because curriculum changes are often a major problem facing the world of education. These changes require many aspects, starting from the readiness of schools, teachers, and students (Ramdani., 2022; Wigati et al., 2023). Increased accessibility and more visionary educational reform goals compel students in Indonesia to strive harder to acquire these skills (Warsihna et al., 2023). In addition, the diverse demographic differences in the regions, characteristics of the learning environment, and unequal resources are additional predictors of the importance of strengthening cognitive flexibility (Ramdani et al., 2021).

Cultural variations have been reported through the diversity of individual executive function development. In the US, rule-switching flexibility shows an increase in early childhood, in contrast to children in South Africa. Rule-switching flexibility depends on certain types of cultural experiences, while word-learning flexibility, is less culturally varied (Legare et al., 2018). Research on cognitive flexibility is often associated with problem-focused coping and the role of other learning variables (Aprianto et al., 2021; Oktaviani et al., 2021). Experimental research including cognitive flexibility was conducted Aprianto et al. (2021), but the procedures carried out were not clearly described. Therefore, a clear picture of the right learning model has not been provided for improving cognitive flexibility.

The diversity in various aspects of education, coupled with the current independent curriculum policy opens up opportunities to learn with a differentiated instruction model. In this context, differentiated instruction emphasizes the excellence and diversity of students as the main benchmark in providing learning relevant to the conditions (Kahmann et al., 2022; Sharp et al., 2020). Theoretically, this principle further strengthens the function of cognitive flexibility. Teachers can provide a variety of activities requiring students to learn actively and adaptively. Students can also be trained by using the abundant environmental resources. Therefore, there is a rationale for considering differentiated instruction as a learning strategy in line with independent curriculum policy and cognitive functions in students.

Differentiated instruction is a relevant learning model to be applied in improving cognitive flexibility. Based on research on human cognitive architecture, cognitive flexibility is related to the interaction of information stored in memory (Eriksson et al., 2015; Sylvia, 2019). Teachers can design learning activities

related to the diversity of children such as interests and talents, learning styles, as well as experiences (Ramdani et al., 2022), including background knowledge. The initial conditions of learning are information schemes that have been formed in long-term memory and should be repeated during the learning process to increase the complexity of existing information (Hartshorne and Makovski, 2019). This process will influence learning and self-efficacy, leading to improvement (Wang and Jou, 2023).

The differentiated learning model is fairly complex because the concept includes a specific part of the individual and the resources possessed. Several activities carried out in differentiated learning have a direct role in training responsiveness to be ready to face existing academic problems (Variacion et al., 2021). Students will be taught skills in conducting self-evaluation, self-reflection, and using limited resources more optimally (Griful-Freixenet et al., 2020; Seddon et al., 2021; Variacion et al., 2021). Therefore, activities in differentiated learning strive to strengthen cognitive flexibility (Griful-Freixenet et al., 2020, 2020; Seddon et al., 2021; Variacion et al., 2021).

According to Veraksa et al. (2020), differentiated instruction given to elementary school students through identical activities can improve cognitive functions. Another research reported that cognitive abilities were improved through differentiated instruction by considering readiness and adjustment to different contexts, situations, and individuals (Stollman et al., 2019). In Indonesia, there has been no research that directly identifies the effectiveness of providing differentiated instruction. In developing cognitive flexibility, students of school age or categorized as adolescents tend to learn faster than adults, with changes in processing in the anterior insula of individuals (Hauser et al., 2015). Therefore, this research aimed to determine the effectiveness of differentiated instruction training in improving cognitive flexibility in students. More comprehensive recommendations are provided with an effective program model for improving the cognitive flexibility needed by Indonesian students.

Materials and Methods

Research Design and Ethical Approval

This research uses an experimental method with a one-group pretest-posttest design model (Knapp, 2016). The experimental model is used to measure the intervention given to a group of participants by comparing the values at the beginning and the end of the measurement. The experiment was carried out by measuring the initial conditions of the participants. At a certain time, the participants were given treatment predicted to improve initial conditions to be more optimal. After the intervention was given, measurement was carried out using the same instrument to determine the final condition. The significance of the changes will determine the success or failure of the experiment. To minimize bias in measurement, the researchers ensured that the experimental study was conducted objectively in terms of manipulation, observation, and control. Additionally, this study was overseen by an ethics committee responsible for ensuring that the activities were conducted in accordance with established research ethics. This research has received approval and passed the feasibility test by the Social Sciences and Humanities Ethics Commission of the National Research and Innovation Agency (BRIN) of Indonesia with number 173/K3.01/SK/04/2023.

Participants

The research populations were students at one of the Junior high schools in Bandung City. These individuals are at the adolescent development level where the optimization of cognitive function becomes very important, specifically in supporting the opportunity for academic success (Herting and Chu, 2017; Steinberg, 2005). The number of participants in the population was 500 (180 students in grade VII, 170 in grade VIII, and 150 in grade XI). In addition, participant willingness sheets were distributed to obtain students willing to be part of the research. The researchers provided an informed consent form that clearly outlines the agreement between the researchers and participants. This includes the benefits that participants may gain, the limitations of the study, as well as the freedom to withdraw from the study at any time as per the agreed terms. Since the participants are still in their adolescent years, we also ensured that permission was obtained from the school, teachers, and parents involved.

The selection method used a convenience sampling system to obtain suitable samples (Bhardwaj, 2019; Etikan, 2016). In this study, the sample consisted of individuals who voluntarily agreed to participate

in the research. This study employed a one-group approach because the researchers aimed to provide a comprehensive intervention to all participants, and therefore, no participants were assigned to a control group. However, the researchers will still selectively filter the data based on the completeness of the information provided by the participants.

Measurement Instrument

The Cognitive Flexibility Inventory developed by Dennis and Vander Wal (2010) was used to measure cognitive flexibility in participants. This instrument measures the attitude in facing challenges and changing maladaptive thoughts for the better. The instrument consists of 20 items that measure 3 dimensions of individual cognitive flexibility, namely, the tendency to embrace difficult situations, the ability to accept alternative explanations, and the ability to apply alternative solutions. There are 7 alternative answers provided in the instrument ranging from 1-7. A score of 1 shows that the individual strongly disagrees with the statements and conditions given in the instrument. Meanwhile, a score of 7 indicates a strong agreement with the statements.

The instrument used was first adapted into Indonesian in adjusting to the language and culture of the participants. This adaptation process refers to the guidelines explained by Beaton et al. (2000), namely translation, synthesis, back translation, expert committee review, and pretesting. The research comprised two expert translators who had more than 2 years of cultural experience abroad and six experts conducting the final review of the adaptation instrument. The final instrument was first tested on 1375 adolescent students, producing a reliability coefficient of .797 and showing a fit model in the validity test with confirmatory analysis.

Experimental Procedure

The experimental activities were carried out through the preparation, implementation, and evaluation phases. The preparation phase starts with selecting a trainer, namely a teacher who has a background in science expertise at each class level. These characteristics were selected based on several previous research where the implementation of differentiated instruction is effective in science subjects (Mathematics, Biology, Physics, and Chemistry). This is because the learning practices are operational and integrate natural resources around the school environment (Sharp et al., 2020; Tomlinson and Jarvis, 2009). After getting a teacher as a trainer, the research team provided training and reinforcement regarding the urgency and use of the differentiated instruction guidebook. At the end of the phase, the trainer made a plan and schedule for implementing the experiment and identified factors affecting the final results. For further details, please see Figure 1, which shows the experimental scheme.

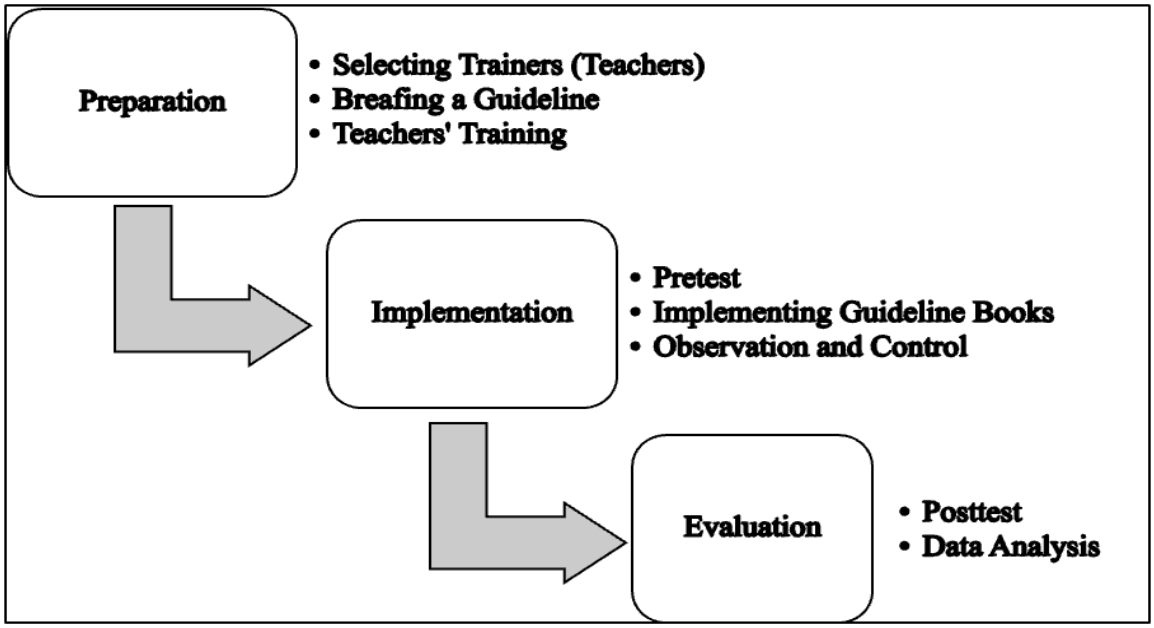


Figure 1. Experimental Scheme

The implementation phase begins by carrying out activities based on the differentiated instruction guidebook. This experimental research was conducted using a validated guidebook. The guide has been provided in soft file form, and the manuscript is published in international proceedings (Ramdani et al., 2022). This instruction guidebook contains general concepts, implementations, and learning practices based on the principle of differentiated learning. The guidebook consists of 7 parts covering the general concept of instruction, learning planning strategies, design, implementation, determining time, identifying learning complexity, and integrating diversity. In each part, there is a worksheet used by teachers to evaluate the learning process. Detailed information for each section will be explained in Table 1 below.

Table 1. *Summary of Differentiated Learning Guidebook Activities*

No	Book Section	Activity	Time
1	General Concept of Instruction	Introduction of concepts and their integration with subject matter	Week 1
2	Learning Planning Strategies	Identifying the learning strategies to be used	Week 1
3	Learning Design	Design in detail every activity that will be carried out	Week 1
4	Determining Time	Make a detailed schedule	Week 1
5	Learning Implementation	Implementation of learning in class with elaboration of material and student conditions	Week 2-4
6	Learning Complexity	Identification of difficulties and relevance of classroom atmosphere	Week 2-4
7	Integrating Diversity	Integration of student needs with learning targets and designs	Week 2-4

Note. The time information given in this book may be adjusted to the field conditions found by the teacher during the experimental process.

The differentiated instruction guidebook has been tested through 2 stages (Ramdani et al., 2022). The first stage was evaluated by experts consisting of lecturers, education practitioners, and external supervisors to obtain input in terms of theoretical framework and implementation. Meanwhile, the second stage of testing was carried out on teachers in 4 different schools as a strategy to determine the readability and usability of the book in learning. The results of the second stage of testing improved the quality of the guidebook to be more practical and on target (Ramdani et al., 2022).

This experimental activity was performed in 3 different classes at the same level (VII, VIII, and IX). The formation has also been agreed on with the school without interfering with normal learning. In addition, the experimental activity was carried out in the first month of the new semester of learning since the school was in the initial administration process. This experiment was performed for 4 weeks, with 2 days each week used by the trainer to implement the guidebook. Implementation was carried out with the learning materials provided by the trainer in class. The trainer was asked to make documentation in the form of photos, activity reports, and general notes on attitudes and behavior during the intervention. This is useful in helping and strengthening the analysis and interpretation process (Baroroh et al., 2024; Rafida and Astuti, 2024). In the final phase, the research collects the results of filling out the questionnaire at the pretest and posttest stages. Additionally, the trainer evaluated the experimental process, and the raw data obtained was prepared for analysis according to the research objectives.

Data Analysis and Interpretation

The data obtained will be analyzed descriptively and inferentially. Descriptive analysis is used to describe the percentage of participant achievement in filling out the questionnaire. Meanwhile, inferential analysis is used to determine the effectiveness of the intervention given to the experimental group. To facilitate the analysis of descriptive and inferential data, the research used SPSS 27 software. Additionally, Rasch Model analysis was conducted using Winstep 3.65 software to ensure unbiased data and identify changes in participant performance. Changes in individual student attitudes were determined by

comparing the pretest and posttest logit (measure) values using the Stacking Rasch Model (Bond and Fox, 2015). The intervention can improve psychological variables in participants when the analysis results are significant (P < .05).

Results

Participant Demographics

A total of 120 students filled out the consent form provided and only 70 filled in the data completely. Demographic data from the 70 participants are presented in Table 2.

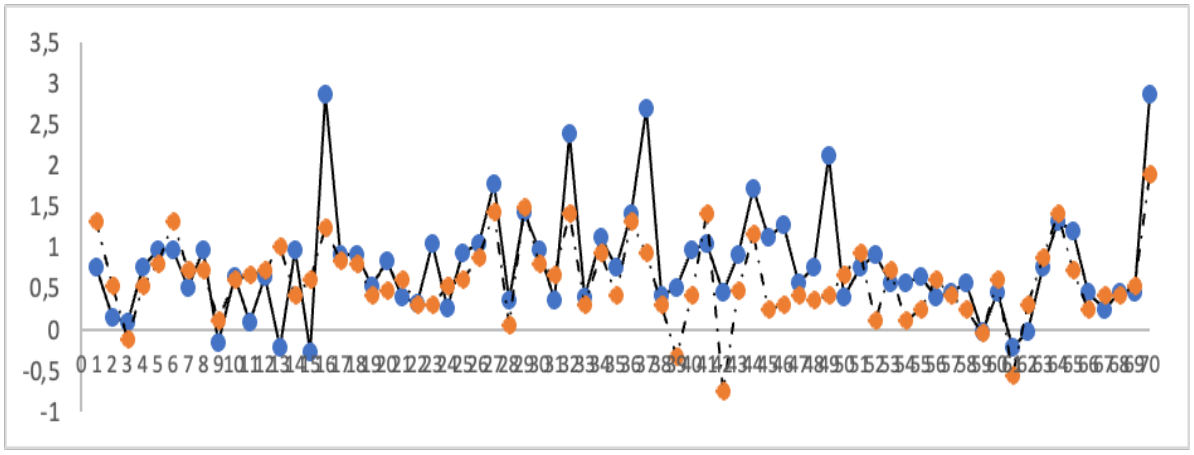
Table 2. *Participant Demographic Data*

Category	Frequency	Percentage (%)
Gender		
Male	35	50
Female	35	50
Age		
12 years	20	28.6
13 years	25	35.7
14 years	21	30
15 years	4	5.7
Class Level		
Class VII	21	30
Class VIII	25	35.7
Class IX	24	34.4

Based on Table 2, the number of male and female participants is the same. From the age data, participants in the 13 and 15-year-old groups reach 35.7% and 5.7%, respectively. The age of the participants ranges from 12 to 15 years old at the adolescent development level (Zhang et al., 2016). Based on the class level, there was no significant difference since the categories were in the range of 30%.

Student Achievement Fluctuation Pretest and Posttest

The raw scores obtained by participants during the pretest and posttest were analyzed using the Rasch Model to obtain the logit value (See Figure 2). In this context, the logit value is a new unit produced by the analysis as the initial answer given in filling out the scale. Therefore, this value can be used as data to be analyzed (Bond and Fox, 2015; Wright, 1977).



Note. Red Line> Pretest Score and Blue Line> Posttest Score

Figure 2. Changes in Participants' Cognitive Flexibility Scores

According to Figure 2, the red and blue lines show the measurements before and after the intervention. Descriptively, there were different changes between one participant and another. However, when viewed, there were 46 participants (66%) who experienced an increase in cognitive flexibility scores during the research process. The results of the score changes were carried out by comparing the size of the pretest and posttest logit (measure) values using the Stacking Rasch Model (Wright, 1977). The analysis showed that the average value of participants in the pretest measurement was 0.601 and 0.798 in the posttest, with a change score of 0.196. A normality analysis was performed to determine the distribution of data before conducting a difference test.

Table 3. *Results of the Data Normality Test*

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pretest	.096	70	.187	.971	70	.099
Posttest	.152	70	.000	.891	70	.000
Pretest-Posttest	.109	140	.000	.925	140	.000

In Table 3, the normality test is performed to determine the normal distribution of data. A test performed on a single group using Kolmogorov-Smirnov or Shapiro-Wilk analysis shows that only the pretest data is normal. This is indicated by a significance value above the standard (p> .05). Meanwhile, when the analysis is performed on a combined group (Pretest-Posttest), the results are not significant (p<.05). Further analysis should be carried out using the Wilcoxon Signed Ranks Test to determine the significance of changes in abnormal data.

Table 4. *Results of the Pretest and Posttest Difference Test*

	N	Mean Rank	Sum of Ranks	Z	Sig.
Negative Ranks	24	31.73	761.50	-2.815	.005
Positive Ranks	46	37.47	1723.50		
Total	70				

Note. Asymp Sig. (2-tailed)

Based on the information in Table 4, the number of participants who experienced an increase and decrease in score was 46 and 24 individuals, respectively. The significance results showed a score of .005 (p < .05) (Hair et al., 2019). From these results, there was a significant change from the pretest to the posttest score. Interpretatively, these results show that intervention in the form of discovery learning can increase cognitive flexibility in adolescent students in this research.

Discussions

This research was conducted by implementing a learning program based on a guidebook created in previous research. In general, a guidebook aims to provide the most practical information possible from a learning concept into a more operational activity for users. The differentiated instruction guidebook was able to contribute significantly to increasing the cognitive flexibility of adolescent students. This certainly shows the relevance between the intervention given and the target behavior. Consistency between the form of intervention and the content being measured is an absolute in experimental research (Gopalan et al., 2020; Jiménez-Buedo and Russo, 2021).

An advantage of an experimental design using only one group is allowing participants to obtain the required positive intervention (Chen et al., 2021; Little et al., 2020). In practice, differentiated instruction contains operational steps that help students master a lesson in class by considering abilities and supporting resources. In several activity sessions, the teacher allows students to work on assignments according to the learning type. Students with a visual learning type can create assignments using certain illustrations. The activities are not only humanistic for students but can be a stimulus to activate cognitive functions in learning (Pham, 2011; Veraksa et al., 2020). So that their cognitive flexibility abilities can be further honed.

Based on the results of the comparison between the pretest and posttest, there was an increase in cognitive flexibility scores in students with a percentage of 66%. This number has exceeded the average percentage value statistically. Therefore, the majority of students obtained an increase in cognitive flexibility because of the differentiated instruction given. Several factors that contribute to the increase can be explained in different situations. First, student participation in the experimental activity is based on a needs analysis, hence the students are enthusiastic and possess the willingness to change for the better (Ma, 2020; Sun et al., 2021).

The results of observations made by the teacher as a trainer obtain several inspirations when implementing differentiated instruction in the classroom. In addition to the method used being more comprehensive in capturing diversity, teachers also get a picture of more enthusiastic students. Since the basic principle of differentiated instruction is to use surrounding resources as learning inspiration, the model can also improve creativity, collaboration, and other cognitive functions such as cognitive flexibility, critical thinking, and problem-solving (Ginja and Chen, 2020; Magableh and Abdullah, 2021; Pozas et al., 2023). Therefore, activities carried out in class using differentiated instruction will strengthen the psychological variables.

The success of this research is also largely determined by the skills possessed by the trainers. As teachers and trainers in implementing this experiment, many factors contribute to the success of the experiment. Teachers are the main key in implementing the education curriculum, hence the ability to capture existing policies adjusted to the situation in the classroom is a privilege (Kneen et al., 2023). The differentiated instruction guidebook provided in this experiment is a practical book for translating the current curriculum into actual language and learning activities (Ramdani et al., 2022b). Great teachers are those who can theoretically understand the concept of differentiated instruction and manifest the concept in adaptive classroom learning. Therefore, teachers as trainers also make a total effort to provide intervention to students. The guidebook promotes the implementation of the current education curriculum. Some worksheets and evaluations can be used to measure the learning process carried out to easily assess students.

The improvement results were strengthened by significant inferential analysis ($p > .05$). There was a significant difference between the pretest and posttest results of the participants. In this research, intervention in the form of differentiated instruction can be an effective strategy for increasing cognitive flexibility. Cognitive flexibility can be strengthened through an effective learning process. However, the measurements carried out in this research only included individual attitude factors. These attitude factors are measured through self-report instruments in several psychological statements. In the implementation, the biases affected small aspects of the experiment (Giromini et al., 2022; Van Berkel et al., 2020). For example, only 66% of participants in this research were obtained and others experienced a decrease in the cognitive flexibility index. Factors such as child readiness and the conduciveness of the learning environment were also considered with the potential bias arising from the use of self-report instruments (Ejelöv and Luke, 2020; Plucker and Makel, 2021; Van Berkel et al., 2020).

The results of data normality show that the distribution of data is not normal but statistically valid. The differences in class levels also contribute to the abnormality of the data with filling out self-reports which tend to be subjective. There are 3 different class levels in the experimental group. A different analysis was not conducted because each level has different challenges (Alcantara et al., 2017). Meanwhile, the research time conducted within 1 month is also important in considering the learning process applied comprehensively.

This study makes a significant contribution to the provision of effective interventions within the educational system in Indonesia. However, more universally, this study could be conducted in the context of more heterogeneous cultures and countries, and even with different age groups or participant categories. The theoretical model derived in this study can be applied within the context of local wisdom. This means that when the experiment is to be replicated in different contexts, it is certainly possible, but it should first involve adapting the teaching materials and considering the differences in participant characteristics specific to each country. Many studies have successfully replicated such experiments in various contexts. The success of these replications is undoubtedly influenced by several factors, including the relevance and consistency of the philosophical principles used, the accuracy and rigidity of the methodology, the implementation procedures, and the critical evaluation of successes and failures in previous related studies (Kim, 2019; Plucker and Makel, 2021). Considering these factors, this study has the potential to be applied across cultures.

The development of differentiated instruction interventions to improve cognitive flexibility will not stop with this study alone. Further studies are needed to strengthen both the results and the weaknesses

identified. This study was conducted within the local school context, but it can be expected to serve as an alternative model at the global level for educational policy development. Furthermore, the issue of cognitive flexibility addressed in this study is a critical aspect that has become a concern for the government to improve. Thus, this study could serve as an alternative approach to developing these skills. However, many challenges may arise in the implementation process, such as the need for a deep understanding among teachers in various regions regarding the concepts presented. One of the limitations in Indonesia is the difference in the educational structure across regions, which heavily depends on the availability of qualified human resources. Meanwhile, the considerable cost required for numerous training programs will also be an important consideration in this context. If all aspects of education are willing to collaborate to improve the quality of education, then the program developed based on this study could become the best solution for advancing education in Indonesia.

This research has several limitations that can be used in the future as reference material. The number of participants is high for 1 class (70 students), which is considered to affect the learning climate and student performance. Theoretically, there is an effective limit to the number of students in 1 class to learn (Khan and Ghosh, 2021). Future research should increase the number of classes when used as a control group. Meanwhile, the learning process carried out in 1 month should be improved concerning the administrative process.

Conclusions

In conclusion, this experimental research emphasized the role of differentiated instruction in improving cognitive flexibility in adolescent students in Indonesia. The results provided a clear picture of classroom learning practices and activities carried out by teachers as an effective strategy for improving skills. Cognitive flexibility could be optimized as an important characteristic for adolescent students in this modern era. However, the strategy could be relevant to the current curriculum policy in training cognitive aspects with the existence of a learning model such as differentiated instruction. Even though this research was conducted in the context of Indonesian schools, the existing learning model could be applied on a global basis due to the nature of differentiated instruction. Therefore, this research could be a best practice in implementing effective learning, as well as strengthening the uniqueness of the students.

Data Availability Statement

All data used in this study are accessible on the following open-access platform https://osf.io/uty7d/.

Funding Statement

This study was funded by the National Research and Innovation Agency (BRIN) of the Republic of Indonesia under grant number B-577/III.7/HM.06.02/2/2023.

Conflict of Interest Disclosure

We declare that there is no conflict of interest in the preparation of this manuscript.

Ethics Approval Statement

This study obtained ethical approval from the Social Sciences and Humanities Ethics Committee of the National Research and Innovation Agency under reference number 173/KE.01/SK/04/2023.

Patient Consent Statement

All participants involved in this study consciously and voluntarily participated in the research, as evidenced by the informed consent they completed before the commencement of the study.

Permission to Reproduce Material from Other Sources

The authors declare that all tables and figures presented in this study are entirely the original work created by the researchers themselves.

Clinical Trial Registration

This study does not contain any clinical material requiring specific registration. However, the researchers registered all research processes with the ethics committee of the National Research and Innovation Agency (BRIN) of the Republic of Indonesia, and all data obtained from the study are accessible on the international platform OSF.

Acknowledgments

The authors are grateful to all the respondents and the academic community of Badan Riset Inovasi Nasional (BRIN) for supporting the publication of this manuscript.

Author Contributions

Conceptualization, Z.R., D.H., and M.F.; methodology, Z.R., D.H., and NS.; software, N.A., A.A., and H.C.; formal analysis, Z.R., and D.H.; writing—original draft preparation, Z.R., D.H., M.F., N.S., and N.A.; writing—review and editing, Z.R., D.H., A.A., and H.C. All authors have read and agreed to the published version of the manuscript.

References

Alcantara, S. C., González-Carrasco, M., Montserrat, C., Viñas, F., Casas, F., & Abreu, D. P. (2017). Peer violence in the school environment and its relationship with subjective well-being and perceived social support among children and adolescents in Northeastern Brazil. *Journal of Happiness Studies,* 18(5), 1507–1532. https://doi.org/10.1007/s10902-016-9786-1

Amir, L. R., Tanti, I., Maharani, D. A., Wimardhani, Y. S., Julia, V., Sulijaya, B., & Puspitawati, R. (2020). Student perspective of classroom and distance learning during COVID-19 pandemic in the undergraduate dental study program Universitas Indonesia. *BMC Medical Education,* 20(1), 392. https://doi.org/10.1186/s12909-020-02312-0

Aprianto, A., Praherdhiono, H., & Wedi, A. (2021). Pengaruh pembelajaran berbasis masalah dengan penguatan keterampilan fleksibilitas terhadap hasil belajar kognitif. *Edcomtech: Jurnal Kajian Teknologi Pendidikan,* 6(2), 264–274. https://doi.org/10.17977/um039v6i12021p264

Baroroh, E. Z., Utimadini, N. J., Alhumairah, N. D., & Fatiah, R. A. (2024). Enhancing self Esteem of orphan teenagers through self-discovery training. *Psympathic: Jurnal Ilmiah Psikologi,* 11(1), 79–90. https://doi.org/10.15575/psy.v11i1.30970

Beaton, D. E., Bombardier, C., Guillemin, F., & Ferraz, M. B. (2000). Guidelines for the process of cross-cultural adaptation of self-report measures: *Spine,* 25(24), 3186–3191. https://doi.org/10.1097/00007632-200012150-00014

Bhardwaj, P. (2019). Types of sampling in research. *Journal of the Practice of Cardiovascular Sciences,* 5(3), 157–163. https://doi.org/10.4103/jpcs.jpcs_62_19

Bond, T. G., & Fox, C. M. (2015). Applying the Rasch model: Fundamental measurement in the human sciences (Third edition). Routledge, Taylor and Francis Group.

Braem, S., & Egner, T. (2018). Getting a grip on cognitive flexibility. *Current Directions in Psychological Science,* 27(6), 470–476. https://doi.org/10.1177/0963721418787475

Buttelmann, F., & Karbach, J. (2017). Development and plasticity of cognitive flexibility in early and middle childhood. *Frontiers in Psychology, 8*, 1040. https://doi.org/10.3389/fpsyg.2017.01040

Chen, C.-A., Hsieh, C.-W., & Chen, D.-Y. (2021). Can training enhance public employees' public service motivation? A pretest–posttest design. *Review of Public Personnel Administration,* 41(1), 194–215. https://doi.org/10.1177/0734371X19872244

Coubard, O. (2011). Practice of contemporary dance improves cognitive flexibility in aging. *Frontiers in Aging Neuroscience,* 3, 1–12. https://doi.org/10.3389/fnagi.2011.00013

Dajani, D. R., Odriozola, P., Winters, M., Voorhies, W., Marcano, S., Baez, A., M. Gates, K., Dick, A. S., & Uddin, L. Q. (2020). Measuring cognitive flexibility with the flexible item selection task: From fmri adaptation to individual connectome mapping. *Journal of Cognitive Neuroscience,* 32(6), 1026–1045. https://doi.org/10.1162/jocn_a_01536

Dajani, D. R., & Uddin, L. Q. (2015). Demystifying cognitive flexibility: Implications for clinical and developmental neuroscience. *Trends in Neurosciences,* 38(9), 571–578. https://doi.org/10.1016/j.tins.2015.07.003

Dargan, S., Kumar, M., Ayyagari, M. R., & Kumar, G. (2020). A survey of deep learning and its applications: A new paradigm to machine learning. *Archives of Computational Methods in Engineering, 27*(4), 1071–1092. https://doi.org/10.1007/s11831-019-09344-w

Dennis, J. P., & Vander Wal, J. S. (2010). The cognitive flexibility inventory: Instrument development and estimates of reliability and validity. *Cognitive Therapy and Research,* 34(3), 241–253. https://doi.org/10.1007/s10608-009-9276-4

Duriez, P., Kaya Lefèvre, H., Di Lodovico, L., Viltart, O., & Gorwood, P. (2021). Increased cognitive flexibility mediates the improvement of eating disorders symptoms, depressive symptoms and level of daily life functioning in patients with anorexia nervosa treated in specialised centres. *European Eating Disorders Review,* 29(4), 600–610. https://doi.org/10.1002/erv.2829

Ejelöv, E., & Luke, T. J. (2020). "Rarely safe to assume": Evaluating the use and interpretation of manipulation checks in experimental social psychology. *Journal of Experimental Social Psychology,* 87*,* 103937. https://doi.org/10.1016/j.jesp.2019.103937

Eriksson, J., Vogel, E. K., Lansner, A., Bergström, F., & Nyberg, L. (2015). Neurocognitive architecture of working memory. *Neuron,* 88(1), 33–46. https://doi.org/10.1016/j.neuron.2015.09.020

Etikan, I. (2016). Comparison of convenience sampling and purposive sampling. *American Journal of Theoretical and Applied Statistics,* 5*(*1), 1–4. https://doi.org/10.11648/j.ajtas.20160501.11

Ginja, T. G., & Chen, X. (2020). Teacher educators' perspectives and experiences towards differentiated instruction. *International Journal of Instruction,* 13*(*4), 781–798. https://doi.org/10.29333/iji.2020.13448a

Giromini, L., Young, G., & Sellbom, M. (2022). Assessing negative response bias using self-report measures: New articles, new issues. *Psychological Injury and Law,* 15(1), 1–21. https://doi.org/10.1007/s12207-022-09444-2

Gopalan, M., Rosinger, K., & Ahn, J. B. (2020). Use of quasi-experimental research designs in education research: Growth, promise, and challenges. *Review of Research in Education,* 44(1), 218–243. https://doi.org/10.3102/0091732X20903302

Griful-Freixenet, J., Vantieghem, W., Gheyssens, E., & Struyven, K. (2020). Connecting beliefs, noticing and differentiated teaching practices: A study among pre-service teachers and teachers. I*nternational Journal of Inclusive Education,* 1–18. https://doi.org/10.1080/13603116.2020.1862404

Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2019). *Multivariate data analysis (8th ed)*. Cengage Learning EMEA.

Hartshorne, J. K., & Makovski, T. (2019). The effect of working memory maintenance on long-term memory. *Memory & Cognition,* 47(4), 749–763. https://doi.org/10.3758/s13421-019-00908-6

Hauser, T. U., Iannaccone, R., Walitza, S., Brandeis, D., & Brem, S. (2015). Cognitive flexibility in adolescence: Neural and behavioral mechanisms of reward prediction error processing in adaptive decision-making during development. *NeuroImage,* 104, 347–354. https://doi.org/10.1016/j.neuroimage.2014.09.018

Herting, M. M., & Chu, X. (2017). Exercise, cognition, and the adolescent brain. *Birth Defects Research,* 109*(*20), 1672–1679. https://doi.org/10.1002/bdr2.1178

Ionescu, T. (2012). Exploring the nature of cognitive flexibility. *New Ideas in Psychology,* 30(2), 190–200. https://doi.org/10.1016/j.newideapsych.2011.11.001

Jiménez-Buedo, M., & Russo, F. (2021). Experimental practices and objectivity in the social sciences: Re-embedding construct validity in the internal–external validity distinction. *Synthese,* 199(3–4), 9549–9579. https://doi.org/10.1007/s11229-021-03215-3

Kahmann, R., Droop, M., & Lazonder, A. W. (2022). Meta-analysis of professional development programs in differentiated instruction. I*nternational Journal of Educational Research,* 116, 102072. https://doi.org/10.1016/j.ijer.2022.102072

Kehagia, A. A., Murray, G. K., & Robbins, T. W. (2010). Learning and cognitive flexibility: Frontostriatal function and monoaminergic modulation. *Current Opinion in Neurobiology,* 20(2), 199–204. https://doi.org/10.1016/j.conb.2010.01.007

Khan, A., & Ghosh, S. K. (2021). Student performance analysis and prediction in classroom learning: A review of educational data mining studies. *Education and Information Technologies,* 26(1), 205–240. https://doi.org/10.1007/s10639-020-10230-3

Kim, J. S. (2019). Making every study count: Learning from replication failure to improve intervention research. *Educational Researcher,* 48(9), 599–607. https://doi.org/10.3102/0013189X19891428

Knapp, T. R. (2016). Why is the one-group pretest–posttest design still used? *Clinical Nursing Research,* 25(5), 467–472. https://doi.org/10.1177/1054773816666280

Kneen, J., Breeze, T., Thayer, E., John, V., & Davies-Barnes, S. (2023). Pioneer teachers: How far can individual teachers achieve agency within curriculum development? *Journal of Educational Change,* 24(2), 243–264. https://doi.org/10.1007/s10833-021-09441-3

Legare, C. H., Dale, M. T., Kim, S. Y., & Deák, G. O. (2018). Cultural variation in cognitive flexibility reveals diversity in the development of executive functions. *Scientific Reports,* 8(1), 16326. https://doi.org/10.1038/s41598-018-34756-2

Leimar, O., Quiñones, A. E., & Bshary, R. (2024). Flexible learning in complex worlds. *Behavioral Ecology,* 35(1), arad109. https://doi.org/10.1093/beheco/arad109

Little, T. D., Chang, R., Gorrall, B. K., Waggenspack, L., Fukuda, E., Allen, P. J., & Noam, G. G. (2020). The retrospective pretest–posttest design redux: On its validity as an alternative to traditional pretest–posttest measurement. *International Journal of Behavioral Development,* 44(2), 175–183. https://doi.org/10.1177/0165025419877973

Ma, Z. (2020). Effects of immersive stories on prosocial attitudes and willingness to help: Testing psychological mechanisms. *Media Psychology,* 23(6), 865–890. https://doi.org/10.1080/15213269.2019.1651655

Magableh, I. S. I., & Abdullah, A. (2021). The impact of differentiated instruction on students' reading comprehension attainment in mixed-ability classrooms. *Interchange,* 52*(*2), 255–272. https://doi.org/10.1007/s10780-021-09427-3

Masley, S., Roetzheim, R., & Gualtieri, T. (2009). Aerobic exercise enhances cognitive flexibility. *Journal of Clinical Psychology in Medical Settings,* 16(2), 186–193. https://doi.org/10.1007/s10880-009-9159-6

Oke, A., & Fernandes, F. A. P. (2020). Innovations in teaching and learning: Exploring the perceptions of the education sector on the 4th industrial revolution (4IR). *Journal of Open Innovation: Technology, Market, and Complexity,* 6(2), 31. https://doi.org/10.3390/joitmc6020031

Oktaviani, N. N., Suprapto, P. K., & Mustofa, R. F. (2021). Hubungan antara fleksibilitas kognitif dengan keterampilan pemecahan masalah pada mata pelajaran biologi di MAN Kota Tasikmalaya. *Jurnal Bioterdidik: Wahana Ekspresi Ilmiah,* 9(1), 87–94. https://doi.org/10.23960/jbt.v9i110

Pham, H. L. (2011). Differentiated instruction and the need to integrate teaching and practice. *Journal of College Teaching & Learning (TLC),* 9(1), 13–20. https://doi.org/10.19030/tlc.v9i1.6710

Plucker, J. A., & Makel, M. C. (2021). Replication is important for educational psychology: Recent developments and key issues. *Educational Psychologist,* 56(2), 90–100. https://doi.org/10.1080/00461520.2021.1895796

Pozas, M., Letzel-Alt, V., & Schwab, S. (2023). The effects of differentiated instruction on teachers' stress and job satisfaction. *Teaching and Teacher Education,* 122*,* 103962. https://doi.org/10.1016/j.tate.2022.103962

Rafida, R., & Astuti, B. (2024). The effectiveness of social skills training in improving students' interpersonal communication. *Sympathic: Jurnal Ilmiah Psikologi,* 11(1), 33–44. https://doi.org/10.15575/psy.v11i1.30357

Ramdani, Z., Amri, A., Hadiana, D., Warsihna, J., Anas, Z., & Susanti, S. (2022). Students' diversity and the implementation of adaptive learning and assessment: A systematic literature review. Interdisciplinary Conference of Psychology, Health, and Social Science (ICPHS 2021), Makassar, Indonesia. https://doi.org/10.2991/assehr.k.220203.025

Ramdani, Z., Amri, A., Warsihna, J., Anas, Z., Chandra, D. T., Hadiyana, D., & Nurwiansyah, I. (2022). Implementasi penggunaan buku panduan pembelajaran dan penilaian adaptif pada jenjang SMP. *Diseminasi: Jurnal Pengabdian kepada Masyarakat,* 4(1A), 114–121.

Ramdani, Z., Hadiana, D., Amri, A., Warsihna, J., Widodo, W., Chandra, D. T., & Sopandi, E. (2022). The mediating role of attitude in the correlation between creativity and curiosity regarding the performance of outstanding science teachers. *Jurnal Pendidikan IPA Indonesia,* 11(3), 412–419.

Ramdani, Z., Kembara, M. D., Alhapip, L., Amri, A., Warsihna, J., & Anas, Z. (2021). Teachers' perception and readiness towards adaptive learning in the covid-19 pandemic: Thematical content analysis study. *AL-ISHLAH: Jurnal Pendidikan,* 13(2), 1383–1393. https://doi.org/10.35445/alishlah.v13i2.915

Ramdani, Z., Natanael, Y., Liem, A., Kamil, A. A., Hadiana, D., & Warsihna, J. (2024). Improving students' academic integrity through academic integrity training (AIT) program in higher education. *Journal of Applied Research in Higher Education*, ahead-of-print(ahead-of-print). https://doi.org/10.1108/JARHE-07-2024-0329

Richard's, M. M., Krzemien, D., Valentina, V., Vernucci, S., Zamora, E. V., Comesaña, A., García Coni, A., & Introzzi, I. (2021). Cognitive flexibility in adulthood and advanced age: Evidence of internal and external validity. *Applied Neuropsychology: Adult,* 28(4), 464–478. https://doi.org/10.1080/23279095.2019.1652176

Scheibling-Sève, C., Gvozdic, K., Pasquinelli, E., & Sander, E. (2022). Enhancing cognitive flexibility through a training based on multiple categorization: Developing proportional reasoning in primary school. J*ournal of Numerical Cognition,* 8(3), 443–472. https://doi.org/10.5964/jnc.7661

Seddon, A. L., Law, A. S., Adams, A.-M., & Simmons, F. R. (2021). Individual differences in media multitasking ability: The importance of cognitive flexibility. *Computers in Human Behavior Reports,* 3, 100068. https://doi.org/10.1016/j.chbr.2021.100068

Sharp, K., Jarvis, J. M., & McMillan, J. M. (2020). Leadership for differentiated instruction: Teachers' engagement with on-site professional learning at an Australian secondary school. *International Journal of Inclusive Education,* 24(8), 901–920. https://doi.org/10.1080/13603116.2018.1492639

Steinberg, L. (2005). Cognitive and affective development in adolescence. *Trends in Cognitive Sciences,* 9(2), 69–74. https://doi.org/10.1016/j.tics.2004.12.005

Stollman, S., Meirink, J., Westenberg, M., & Van Driel, J. (2019). Teachers' interactive cognitions of differentiated instruction in a context of student talent development. *Teaching and Teacher Education,* 77, 138–149. https://doi.org/10.1016/j.tate.2018.09.003

Sun, S., Lin, D., & Operario, D. (2021). Interest in COVID-19 vaccine trials participation among young adults in China: Willingness, reasons for hesitancy, and demographic and psychosocial determinants. *Preventive Medicine Reports,* 22*,* 101350. https://doi.org/10.1016/j.pmedr.2021.101350

Sylvia, N. (2019). Pengakomodasian skema kognitif manusia: Pengembangan materi ajar bagi pendidikan bahasa. In Seminar Internasional Riksa Bahasa.

Tello-Ramos, M. C., Branch, C. L., Kozlovsky, D. Y., Pitera, A. M., & Pravosudov, V. V. (2019). Spatial memory and cognitive flexibility trade-offs: To be or not to be flexible, that is the question. *Animal Behaviour,* 147*,* 129–136. https://doi.org/10.1016/j.anbehav.2018.02.019

Themanson, J. R., Pontifex, M. B., & Hillman, C. H. (2008). Fitness and action monitoring: Evidence for improved cognitive flexibility in young adults. *Neuroscience,* 157(2), 319–328. https://doi.org/10.1016/j.neuroscience.2008.09.014

Tomlinson, C. A., & Jarvis, J. M. (2009). Differentiation: Making curriculum work for all students through responsive planning & instruction. In Systems and Models for Developing Programs for the Gifted and Talented (2nd Edition). Routledge.

Uddin, L. Q. (2021). Cognitive and behavioural flexibility: Neural mechanisms and clinical considerations. *Nature Reviews Neuroscience,* 22*(*3), 167–179. https://doi.org/10.1038/s41583-021-00428-w

Van Berkel, N., Goncalves, J., Hosio, S., Sarsenbayeva, Z., Velloso, E., & Kostakos, V. (2020). Overcoming compliance bias in self-report studies: A cross-study analysis. *International Journal of Human-Computer Studies,* 134*,* 1–12. https://doi.org/10.1016/j.ijhcs.2019.10.003

Van Bers, B. M. C. W., Van Schijndel, T. J. P., Visser, I., & Raijmakers, M. E. J. (2020). Cognitive flexibility training has direct and near transfer effects, but no far transfer effects, in preschoolers. *Journal of Experimental Child Psychology,* 193, 104809. https://doi.org/10.1016/j.jecp.2020.104809

Variacion, D. A., Salic-Hairulla, M., & Bagaloyos, J. (2021). Development of differentiated activities in teaching science: Educators' evaluation and self-reflection on differentiation and flexible learning. J*ournal of Physics: Conference Series,* 1835*(*1), 012091. https://doi.org/10.1088/1742-6596/1835/1/012091

Veraksa, A. N., Aslanova, M. S., Bukhalenkova, D. A., Veraksa, N. E., & Liutsko, L. (2020). Assessing the effectiveness of differentiated instructional approaches for teaching math to preschoolers with different levels of executive functions. *Education Sciences,* 10(7), 181. https://doi.org/10.3390/educsci10070181

Wang, J., & Jou, M. (2023). The influence of mobile-learning flipped classrooms on the emotional learning and cognitive flexibility of students of different levels of learning achievement. *Interactive Learning Environments,* 31*(*3), 1309–1321. https://doi.org/10.1080/10494820.2020.1830806

Warsihna, J., Ramdani, Z., Amri, A., Kembara, M. D., Steviano, I., Anas, Z., & Anggraena, Y. (2023). Tantangan dan strategi implementasi kurikulum merdeka pada jenjang SD: Sebuah temuan multi-perspektif. *Kwangsan: Jurnal Teknologi Pendidikan,* 11(1), 296. https://doi.org/10.31800/jtp.kw.v11n1.p296--311

Wigati, I., Mardeli, M., Astuti, M., Yuniar, Y., & Ramdani, Z. (2023). Perception of religious lecturers of higher order thinking skills and students' academic performance in online learning. *International Journal of Learning, Teaching and Educational Research,* 22(4), 124–140. https://doi.org/10.26803/ijlter.22.4.8

Wright, B. D. (1977). Solving measurement problems with the Rasch model. *Journal of Educational Measurement,* 14(2,), 97–116.

Zhang, A. L., Sing, D. C., Rugg, C. M., Feeley, B. T., & Senter, C. (2016). The rise of concussions in the adolescent population. *Orthopaedic Journal of Sports Medicine,* 4(8), 232596711666245. https://doi.org/10.1177/2325967116662458

Zuhdiyah, Z., Khodijah, N., & Ramdani, Z. (2024). Religious belief: An interpretative phenomenological analysis on the experience of minority students in implementing religious education. *Qualitative Research in Education,* 13(3), 243–261. http://dx.doi.org/10.17583/qre.11651