

The Role of Spatial Ability and Metacognitive Skills in Reducing Cognitive Load in Developmental Psychology Courses

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Abstract. This study investigates the degree to which students' spatial abilities and metacognitive skills forecast their cognitive load in a Developmental Psychology course. Data were gathered utilizing a quantitative associative design through self-administered questionnaires assessing spatial aptitude (Santa Barbara Sense of Direction Scale/SBSOD), metacognitive skills (Metacognition Self-Assessment Scale/MSAS), and cognitive load (Paas Cognitive Load Scale). Data were analyzed via PLS-SEM in SmartPLS 3. The findings demonstrate that spatial ability and metacognitive skills significantly and negatively predict cognitive load ($p < .05$), indicating that students with enhanced visuospatial processing and self-regulation perceive reduced mental effort when engaging with complex, diagram-intensive material. The findings underscore the necessity of including visuospatial aids (such as organized visual representations and augmented reality/visual media) and metacognitive supports (including prompts, reflection, and self-monitoring practices) to enhance learning efficacy in cognitively challenging courses.

Keywords: Spatial Ability; Metacognitive Skills; Cognitive Load; Developmental Psychology.

1 Introduction

Understanding humans throughout their lifespan is the core of Developmental Psychology. Its scope is very broad, encompassing physical, cognitive, social, emotional, and moral development from birth to the end of life. This complexity demands that students process large amounts of information at a high level of abstraction [1]. As a result, this material often presents a cognitive challenge because it demands an understanding that connects various concepts and theories, as well as the ability to integrate complex information from different stages of life.

Traditional instruction in Developmental Psychology is still primarily based on lectures and lengthy reading materials. In real classrooms, this technique frequently does not correspond to how kids learn. When asked to read graphs, follow

developmental stage charts, or comprehend abstract concepts, many people become confused rather than assisted. Explanations are frequently overly brief and give little room for reflection. As a result, pupils attempt to memorize terms rather than actually comprehend the concepts. This condition makes learning feel weighty and burdensome, and students struggle to connect psychological ideas to real-world human growth. Classroom instruction frequently remains unaltered, despite the increasing interest in developmental psychology. Students are left to navigate abstract theories and overlapping developmental stages with little support, as lectures and dense literature dominate. Presenting an excessive amount of information at a rapid pace results in a silent conflict for many individuals. When cognitive demands exceed the capacity of learners to manage them, comprehension begins to deteriorate. Rather than fostering engagement, these methods may inadvertently alienate students from the subject matter. It is both urgent and indispensable to reconsider the manner in which we instruct this subject.

Cognitive Load Theory [2] explains that teaching materials that are too dense and poorly organized risk overloading working memory, thus triggering cognitive overload. As a result, the process of understanding the material is hindered, concentration is easily diverted, and information fails to be integrated into meaningful knowledge. The findings of [3] support this. They proved that presentation methods that ignore the basic principles of human information processing actually decrease learning effectiveness and long-term retention. These two studies together confirm one thing: that information organization strategies are not trivial, but rather a crucial element that determines the quality of a learning process.

Recent research further confirms the key role of spatial ability in learning. [4] found that the capacity to manipulate these mental representations of visual objects is very helpful for students in integrating verbal and visual information. As a result, their cognitive load becomes lighter when facing complex tasks. This finding aligns with the report by [5], which indicates that students with superior spatial abilities do not easily experience cognitive overload when solving visual analysis problems. Beyond technical ability, [6] reminds us that a person's self-confidence in dealing with visual material (spatial self-confidence) is also a determining factor in successful information processing in the academic world.

Recent findings reveal an interesting paradox in the world of digital education. Amidst the rise of immersive technologies like augmented reality, spatial ability is becoming increasingly crucial. Studies have shown that although technology can present more engaging visualizations, a deep understanding of complex material still depends on an individual's capacity to manipulate mental representations. This aligns with the research by [4], which shows that technology is merely a tool, while the key to understanding remains with the learner's visuospatial abilities. This finding confirms that investing in the development of basic skills remains relevant in the digital age.

Metacognitive skills are the ability to independently regulate the learning process. Similar to a guide, this skill allows students to plan, monitor, and evaluate the learning methods they use. Research by [7] revealed that students with good metacognitive skills are better able to stay focused and reduce distractions while studying. This ability allows individuals to recognize when their attention begins to wane and make immediate adjustments. As a result, the learning process becomes more effective and cognitive load can be reduced because everyone can find the most suitable learning method for themselves.

Metacognitive skills act like a personal coach in learning, helping us organize our thinking strategies and improve cognitive self-control. Ajayi's research proves that this approach not only reduces excessive mental effort but also improves the quality of understanding, while [8] study shows how metacognition creates a more directed and effective learning process. Ultimately, it is this ability that enables us to become independent learners capable of optimizing information processing while better managing cognitive load.

Various studies strengthen the evidence that metacognitive skills play a direct role in reducing mental load during learning. Research by [9] and [10] shows that metacognitive interventions successfully improve self-monitoring abilities and the selection of appropriate learning strategies, thereby effectively reducing unnecessary cognitive load. The findings from [11] also revealed that using metacognitive prompts, which are cues to reflect on the learning process, helps learners focus on relevant information and ultimately significantly improves their learning outcomes.

Research on instructional strategies to reduce cognitive load has been extensive, but studies on the role of individual cognitive characteristics are still limited. Specifically, the contribution of spatial abilities and metacognitive skills in understanding complex Developmental Psychology material has not been extensively researched. However, these two factors have been proven to help students process information more efficiently when dealing with abstract and multidimensional material like that found in Developmental Psychology.

Although many studies have examined instructional strategies for reducing cognitive load, limited attention has been given to learner characteristics that may help reduce cognitive overload in conceptually demanding courses such as Developmental Psychology. In particular, there aren't many actual studies that look at how spatial ability and metacognitive skills work together to lower cognitive load. Metacognitive skills help learners plan, monitor, and control their mental activities, while spatial skills help them handle visual representations efficiently. This study aims to examine how spatial ability and metacognitive skills predict students' cognitive load in a Developmental Psychology course. By doing this, it will add to the body of research on learner-centered approaches in higher education.

Students are still expected to learn developmental psychology through lengthy textbook readings and lectures in many schools. Despite its extensive history, this approach does not always aid pupils in comprehending the subject matter completely. The topic spans several developmental phases and contains a lot of intricate concepts. Presenting all of this at once may make it too much to handle. Pupils may become disinterested or confused. Some people could have trouble recalling what they have learnt. This does not imply that the subject is uninteresting; rather, it indicates that the curriculum needs to be taught more effectively. Learning is more effective when the material is simpler to understand and has a stronger real-world connection. Simple resources like group discussions, real-world examples, or brief movies can be used by educators. These adjustments can help students stay focused and involved in the classroom while also giving learning greater significance.

2 Research Methods

First-year college students who had taken the Developmental Psychology course at STIKES Mataram took part in this study. A total of 135 students consented to participate. The Santa Barbara Sense of Direction Scale (SBSOD) was used to test spatial ability. It has 15 items that are rated on a seven-point Likert scale that goes from strongly disagree to strongly agree. The Metacognition Self-Assessment Scale (MSAS) was used to assess metacognitive skills. It has 18 items that are rated on a five-point range from "never" to almost always. A single-item measure of mental work created by Paas and rated on a nine-point scale was used to measure cognitive load.

The SmartPLS 3 program was used for data analysis, which included Partial Least Squares-Structural Equation Modeling (PLS-SEM). First, the measurement model was evaluated to ensure that each indicator accurately represented its construct. To confirm convergent validity, we examined outer loadings and Average Variance Extracted (AVE). Discriminant validity was then determined using the Fornell-Larcker criterion and the Heterotrait-Monotrait (HTMT) ratio. After confirming the measurement model, we evaluated the structural model by analyzing path coefficients, significance levels ($p < .05$), effect sizes (f^2), and proportion of variance explained (R^2).

The Paas mental effort scale, which is made up of a single question, was used to measure cognitive load in this study. This single-item scale was used because previous research has shown that learners' direct and subjective ratings of mental effort provide a valid and reliable measure of cognitive load. Many studies on cognitive load use the Paas scale because it can quickly measure perceived mental effort without imposing additional cognitive load during learning. This is a one-item scale, but it is thought to be good for the study goal, which is to look at how people feel about cognitive load in general rather than specific aspects of cognitive load.

3 Results and Discussion

Results

3.1 Respondent Characteristics

This study involved 135 third-semester students from STIKES Mataram who had completed the Developmental Psychology course. The majority of participants were aged 19-22 years, placing them in the early adulthood phase where abstract thinking and cognitive flexibility are already mature [1], [14]. The participant composition is dominated by women, reflecting the general characteristics of healthcare institutions. The findings of [15] and [6] indicate that gender variation can influence spatial abilities and learning strategy preferences, which should be considered in data analysis.

The participants in this study have a uniform educational background as graduates of high school/Islamic senior high school science programs or health schools. This homogeneity minimizes the influence of external factors, making it more likely that variations in academic performance are due to differences in internal cognitive abilities. Spatial ability, self-confidence in processing visual information, and metacognitive skills in organizing learning strategies are key determining factors. The findings of [6], [8], [14] support this by showing that an individual's capacity to monitor their thinking processes and select appropriate learning strategies is crucial for the effectiveness of complex information processing.

The selection of third-semester students as respondents is very appropriate because they are actively studying Developmental Psychology with various abstract concepts and developmental diagrams. Spatial abilities help them understand visual representations like developmental stage charts, while metacognitive skills enable effective learning strategy regulation. Based on research by [4], [11], [15], the combination of these two abilities can reduce cognitive load when processing complex material. Such characteristics of the respondents are very suitable for researching the contribution of spatial and metacognitive abilities to managing cognitive load in Developmental Psychology learning.

3.2 Measurement Model (Outer Model)

Table 1. Measurement Model Assessment Results (Validity and Reliability)

Latent Variable	Item	Outer Loading	AVE	Cronbach's Alpha	Composite Reliability
Spatial Ability	KS1	0.763	0.576	0.947	0.953
	KS2	0.774			
	KS3	0.775			
	KS4	0.722			
	KS5	0.752			
	KS6	0.769			
	KS7	0.742			
	KS8	0.751			

Latent Variable	Item	Outer Loading	AVE	Cronbach's Alpha	Composite Reliability
	KS9	0.759			
	KS10	0.757			
	KS11	0.760			
	KS12	0.738			
	KS13	0.768			
	KS14	0.794			
	KS15	0.762			
Metacognitive Skills	KM1	0.767	0.634	0.966	0.969
	KM2	0.801			
	KM3	0.766			
	KM4	0.856			
	KM5	0.775			
	KM6	0.819			
	KM7	0.797			
	KM8	0.733			
	KM9	0.835			
	KM10	0.793			
	KM11	0.813			
	KM12	0.767			
	KM13	0.792			
	KM14	0.791			
	KM15	0.841			
	KM16	0.802			
	KM17	0.782			
	KM18	0.793			
Cognitive Load	CL1	0.892	0.796	0.957	0.965
	CL2	0.902			
	CL3	0.896			
	CL4	0.897			
	CL5	0.899			
	CL6	0.869			

Latent Variable	Item	Outer Loading	AVE	Cronbach's Alpha	Composite Reliability
	CL7	0.889			

The results of the convergent validity and reliability tests indicate that both the latent variables of spatial ability, metacognitive skills, and cognitive load meet good criteria. Convergent validity is assessed through outer loading values and Average Variance Extracted (AVE). All indicators of all variables have outer loading values greater than 0.7 indicating that each item is able to reflect the latent variable well. The AVE values also exceeded the minimum threshold of 0.5 (Spatial Ability = 0.576; Metacognitive Skills = 0.634; Cognitive Load = 0.796), indicating that each construct has sufficient ability to explain the variance of its indicators.

Table 2. Fornell-Larcker Criterion Values

	Cognitive Load	Spatial Ability	Metacognitive Skills
Cognitive Load	0.892*	-	-
Spatial Ability	-0.608	0.759*	-
Metacognitive Skills	-0.612	0.340	0.796*

Based on the Fornell-Larcker analysis, it can be confirmed that each construct in this study meets discriminant validity. The AVE root values for each variable, namely Cognitive Load (0.892), Spatial Ability (0.759), and Metacognitive Skills (0.796), were proven to be higher than any inter-latent variable correlation. This finding is further supported by the HTMT test results, which show all values are below the 0.85 threshold. Thus, it can be concluded that the three constructs indeed measure different and non-overlapping aspects, so this research instrument is declared valid for accurately measuring each variable.

Table 3. Cross-Loading

Item	Latent Variable		
	Cognitive Load	Spatial Ability	Metacognitive Skills
CL1	0.892	-0.557	-0.563
CL2	0.902	-0.550	-0.560
CL3	0.896	-0.571	-0.499
CL4	0.897	-0.543	-0.596
CL5	0.899	-0.533	-0.537
CL6	0.869	-0.526	-0.542
CL7	0.889	-0.514	-0.516

Item	Latent Variable		
	Cognitive Load	Spatial Ability	Metacognitive Skills
KM1	-0.467	0.302	0.767
KM10	-0.470	0.228	0.793
KM11	-0.556	0.358	0.813
KM12	-0.433	0.181	0.767
KM13	-0.449	0.266	0.792
KM14	-0.498	0.226	0.791
KM15	-0.553	0.369	0.841
KM16	-0.516	0.261	0.802
KM17	-0.523	0.333	0.782
KM18	-0.540	0.253	0.793
KM2	-0.418	0.249	0.801
KM3	-0.470	0.215	0.766
KM4	-0.518	0.212	0.856
KM5	-0.475	0.262	0.775
KM6	-0.481	0.273	0.819
KM7	-0.482	0.290	0.797
KM8	-0.351	0.260	0.733
KM9	-0.491	0.303	0.835
KS1	-0.474	0.763	0.277
KS10	-0.469	0.757	0.350
KS11	-0.515	0.760	0.284
KS12	-0.433	0.738	0.193
KS13	-0.494	0.768	0.288
KS14	-0.445	0.794	0.220
KS15	-0.477	0.762	0.246
KS2	-0.488	0.774	0.261
KS3	-0.446	0.775	0.273
KS4	-0.398	0.722	0.135
KS5	-0.410	0.752	0.243
KS6	-0.423	0.769	0.262
KS7	-0.489	0.742	0.315

Item	Latent Variable		
	Cognitive Load	Spatial Ability	Metacognitive Skills
KS8	-0.422	0.751	0.193
KS9	-0.501	0.759	0.294

The results of the cross-loading analysis indicate the accuracy of measuring each variable. Indicators CL1 to CL7 load most strongly on cognitive load with values of 0.869-0.902, while the correlation with other variables is negative. Indicators KM1-KM18 consistently load high on metacognitive ability (0.733-0.856), and KS1-KS15 are most closely related to spatial ability (0.722-0.794). This finding proves that there is no overlap in measurement between constructs. Each indicator specifically measures the target variable, so this research instrument has adequate discriminant validity to test the relationships between variables.

3.3 Results of Structural Model Assessment

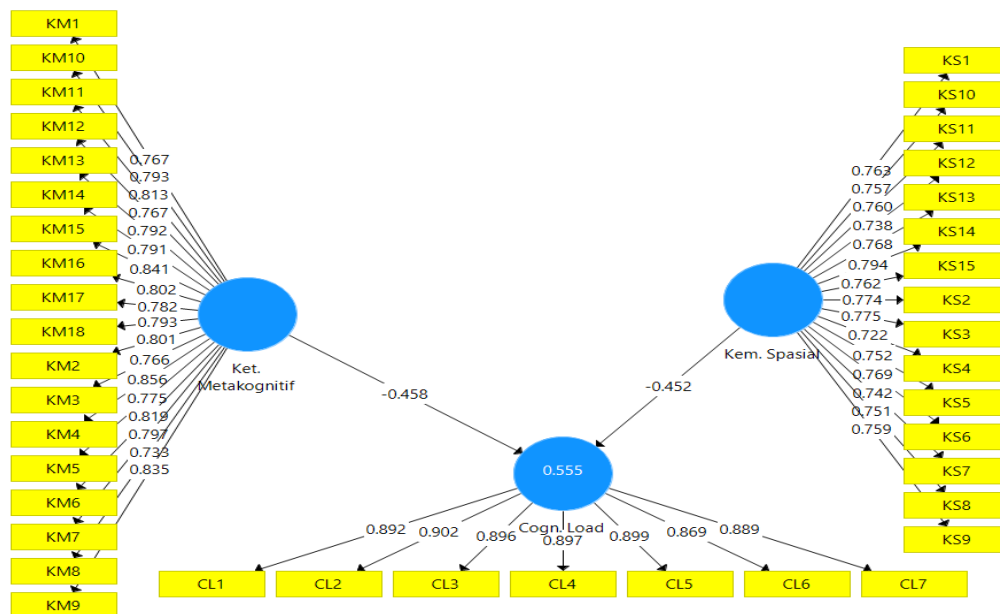


Figure 1. Output of Inner Model Testing Results (Resampling Algorithm Method)

From the PLS analysis, spatial ability and metacognitive skills together are able to explain 55.5% of the variation in cognitive load. This R-squared value of 0.555 becomes 0.548 after adjustment. This value indicates a moderately strong level of explanatory power. This means that more than half of the factors influencing students' cognitive load can be explained by the combination of these two variables. This finding

proves the important role of spatial and metacognitive abilities in determining the severity of cognitive load during learning.

Table 4. Structural Model Assessment Results (Inner Model)

Exogenous Latent Variable	R2	Adjusted R2	Effect Size (F2)
Spatial Ability	0.555	0.548	0.406
Metacognitive Skills			0.416

The effect size f^2 indicates that the two variables have a strong influence. The spatial ability has an f^2 value of 0.406, while the metacognitive ability is slightly higher at 0.416. According to the benchmark by Hair Jr. et al., a value above 0.35 is considered a large effect. So, it can be said that both of these abilities have a significant impact on cognitive load. Both spatial and metacognitive factors equally determine the perceived mental workload of students while learning.

Discussion

The results indicate that spatial ability significantly facilitates students' capacity to manage the cognitive challenges of Developmental Psychology, particularly when the content relies on diagrams, stage models, and visual arrangements. Students with superior spatial reasoning abilities tend to integrate images and explanations more effortlessly, thereby avoiding unnecessary effort in interpreting the visuals. This creates additional mental capacity for comprehending the concepts themselves. Simultaneously, metacognitive abilities enable students to maintain control over their learning process. Through careful planning of their tasks, verifying their comprehension, and adjusting strategies as necessary, they can prevent distractions and maintain focus. When these two capabilities operate in conjunction, students utilize their cognitive resources more efficiently and encounter reduced cognitive load during demanding learning activities. This finding is consistent with [16], which suggests that students with strong visualization skills are better able to focus on core concepts, while [15] also showed that the ability to visualize concepts improves efficiency in learning diagram-rich material. In short, spatial ability is like a key that unlocks the door, making it easier for complex information to enter the brain.

The material on Developmental Psychology contains a number of diagrams about developmental phases, interaction graphs, and complex conceptual models. This visualization is supposed to help with understanding, but it often hinders students with low spatial skills. The process of combining text, illustrations, and oral explanations actually adds to the mental burden and creates confusion. This situation is very different from students who have good visualization skills. Diagrams and graphs are very effective learning aids. The ability to transform images into more abstract concepts

makes it easier to understand the material. Research [5] indicates that students with this ability can effectively connect verbal and visual explanations. As a result, students not only avoid cognitive overload but are also able to process complex information into a more complete and in-depth understanding.

Developing metacognitive skills serves as a control mechanism that allows students to optimize their cognitive resources. When students are able to plan learning strategies, monitor their understanding, and evaluate the effectiveness of their learning methods, they will develop significant cognitive efficiency. [9] findings confirm that metacognitive interventions enhance monitoring abilities, which in turn reduces cognitive effort. Meanwhile, [10] adds that self-regulation practices such as goal setting and self-evaluation effectively reduce extraneous cognitive load. Furthermore, [11] found that metacognitive prompts serve as cues that direct attention to essential information, thereby minimizing cognitive overload. Thus, developing metacognitive skills not only improves academic outcomes but also creates fundamental efficiency in the learning process.

These two variables work complementarily in managing cognitive load. Spatial ability helps students navigate visual complexity, while metacognition helps them organize their thinking, choose strategies, and suppress irrelevant stimuli. This aligns with the integrative framework described by [14], [17], which combines Cognitive Load Theory with Self-Regulated Learning. According to de Bruin, the effectiveness of information processing depends not only on working memory capacity but also on an individual's ability to consciously control and monitor their mental effort.

Developmental Psychology material requires students to understand various theories, stages of development, and the interaction of genetic, environmental, and social factors. Students with high spatial abilities can efficiently organize charts, diagrams, and development flows, while students with strong metacognitive skills can develop learning strategies, identify core information, and break down complex concepts into smaller units. The combination of these two abilities results in optimal working memory allocation and reduces overall cognitive load. Thus, the results of this study are completely in line with the literature reviewed in this study and are supported by strong empirical evidence.

The synthesis of these two factors aligns with [17] integrative model, which asserts that learning effectiveness is determined by the dynamic interaction between cognitive capacity and regulatory abilities. Thus, students with adequate spatial abilities and supported by good metacognitive skills will be more capable of understanding visual-abstract material, managing the complexity of developmental concepts, and maintaining cognitive load at an optimal level. These findings confirm that both abilities are essential foundations for success in learning Developmental Psychology, and therefore require special attention in both instructional design and the development of learning strategies in higher education

4 Conclusion

This research concludes that spatial ability and metacognitive skills are significant predictors of students' cognitive burden in a Developmental Psychology course. Students possessing more advanced visuospatial processing skills and elevated levels of metacognitive regulation encounter reduced mental effort when engaging with complex and representation-intensive material. Practically, educators are advised to integrate structured visual aids and explicit metacognitive scaffolding, including planning prompts and reflective exercises, to mitigate extraneous cognitive load and improve learning outcomes in higher education settings.

The implications of these discoveries are evident in the manner in which we instruct Developmental Psychology. Abstract concepts and developmental stages are often difficult for students to comprehend simultaneously. Instructors can utilize straightforward and well-organized visual aids, such as diagrams that delineate processes in detail or charts that illustrate each stage, to facilitate their students' learning. It is also beneficial to instruct students in anticipating their learning, verifying their comprehension as they progress, and engaging in post-learning reflection. In college classrooms, these minor modifications, when implemented progressively, can contribute to improved student learning and reduce confusion.

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