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Three-Dimensional Science Animation Implementation and Spatial Ability for Science Concept Reconstruction: A Gender-Based Education Study

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ABSTRAK

Kemampuan spasial merupakan aspek penting dalam kehidupan dan perkembangan individu, tetapi perbedaan gender dalam kemampuan ini, terutama dalam konteks penggunaan multimedia pembelajaran, menjadi perhatian. Penelitian ini bertujuan untuk menguji pengaruh gender dan jenis multimedia terhadap hasil belajar Ilmu Pengetahuan Alam (IPA), sambil tetap mengontrol pengaruh kemampuan spasial. Penelitian ini menggunakan pendekatan kuantitatif dengan metode eksperimental. Sampel penelitian terdiri dari 164 mahasiswa. Data dikumpulkan melalui teknik multivariate analysis of covariance (MANCOVA) menggunakan perangkat lunak SPSS. Analisis data dilakukan dengan menggunakan teknik MANCOVA untuk menguji pengaruh variabel independen (gender dan jenis multimedia) terhadap variabel dependen (hasil belajar IPA), dengan mengontrol kemampuan spasial sebagai covariate. Kemampuan spasial memiliki pengaruh yang signifikan secara keseluruhan terhadap hasil belajar IPA. Laki-laki secara konsisten menunjukkan performa yang lebih baik daripada perempuan dalam semua tugas pembelajaran, tanpa dipengaruhi oleh jenis multimedia. Selain itu, perempuan cenderung lebih menyukai media pembelajaran 3D untuk memahami konsep sains. Penelitian ini memberikan bukti empiris tentang efek gender yang terpisah dari kemampuan spasial saat belajar dengan menggunakan multimedia pembelajaran statis 2D dan animasi 3D. Implikasinya, pembuat kebijakan pendidikan dapat memperhatikan perbedaan preferensi gender dalam memilih jenis multimedia pembelajaran untuk meningkatkan efektivitas pembelajaran IPA.

ABSTRACT

Spatial abilities are essential to individual life and development, but gender differences in these abilities, especially in multimedia learning, are of concern. This research aims to examine the influence of gender and type of multimedia on learning outcomes in Natural Sciences (IPA) while still controlling for the influence of spatial abilities. This research uses a quantitative approach with experimental methods. The research sample consisted of 164 students. Data were collected through multivariate analysis of covariance (MANCOVA) techniques using SPSS software. Data analysis was conducted using the MANCOVA technique to test the influence of the independent variables (gender and type of multimedia) on the dependent variable (science learning outcomes) by controlling spatial ability as a covariate. Spatial ability has an overall significant influence on science learning outcomes. Boys consistently performed better than girls in all learning tasks, regardless of multimedia type. Girls also tend to prefer 3D learning media to understand science concepts. This research provides empirical evidence about the separate gender effects of spatial ability when learning using 2D static learning multimedia and 3D animation. The implication is that educational policymakers can pay attention to differences in gender preferences when choosing multimedia learning types to increase the effectiveness of science learning.

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1. INTRODUCTION

The increasing ubiquity of dynamic multimedia-based learning, driven by advancements in information technology, has prompted an endeavor to examine the impact of this multimedia format on educational results. The consistency of empirical evidence regarding the influence of different multimedia forms, specifically static 2D and 3D animation, on learning outcomes is variable. According to previous research, there are difficulties associated with static media when learners are tasked with making inferences about temporal change (Akman et al., 2022; Roslan & Ahmad, 2017). This is because learners are required to generate dynamic material based on static representations. The clear depiction of temporal changes in animation can potentially alleviate the cognitive load associated with maximizing the information transfer process required for inferential learning. According to experts, the utilization of animation yields favorable educational consequences (Knapp et al., 2023; Rajae & Idrissi, 2021; Teplá et al., 2022). However, opposing research results also indicate that animation does not have a clear benefit over static media on learning outcomes due to the transient nature of animation and may create additional cognitive load (Daly et al., 2016; Schnotz et al., 2014). Other research focusing on the differences in learning outcomes with static and dynamic learning media (animation) was extended by investigating additional factors, such as gender, spatial ability, and prior knowledge (Chikha et al., 2021; Li et al., 2022; Strømme & Mork, 2021).

Spatial ability is a cognitive component characterized by the ability to comprehend, visualize, create, and translate information from a visual stimuli into a spatial framework (Ploetzner et al., 2020; Y. Wang et al., 2023). Spatial ability is significantly associated with disciplines in science, technology, engineering, and mathematics (STEM), particularly in the domain of material reconstruction, such as the solar system and the human skeletal system (Ishikawa & Newcombe, 2021; Yan et al., 2023). Individuals with lesser spatial abilities have a tendency to perceive science imagery holistically, rather than as a compilation of distinct elements, necessitating cognitive adjustment for comprehension (Sandra Berney et al., 2015; Cohen & Hegarty, 2014). Certain scholars contend that the utilization of dynamic learning multimedia, such as animations, may be beneficial for those with limited spatial abilities. This is due to the explicit depictions of the interconnectedness between various pictures seen in scientific texts. Nevertheless, critics of this notion contend that dynamic learning media is inherently more intricate due to its inclusion of supplementary procedural information, hence rendering learners with superior spatial abilities more adept at utilizing this particular sort of multimedia (Cohen & Hegarty, 2014; Huang & Lin, 2017).

Several studies have identified gender differences in spatial ability that generally favor males (Barel & Tzischinsky, 2018; Cai et al., 2017; Sneider et al., 2015; L. Wang & Carr, 2014). Although this viewpoint has been widely accepted for a long time, a review of gender cognitive ability studies raises questions about the overall impact and significance of the research conducted. In addition, gender differences in various aspects of visuo-spatial abilities reported in the literature are inconsistent; for instance, gender differences are more pronounced in mental rotation of three-dimensional objects and less pronounced in folding ability (J.C. Castro-Alonso et al., 2019; Voyer et al., 2017). Despite these quantifiable gender differences, other studies concur that spatial abilities are generally malleable, and that specific training techniques can significantly narrow the gender disparity in learning outcomes. Studies on gender differences in 2D static and 3D dynamic (animated) multimedia learning have produced contradictory findings. Previous research found that males tend to demonstrate better learning outcomes using 3D animation technology, while and reported the opposite (Chen et al., 2018; Liu & Elms, 2019; Praveen & Srinivasan, 2022; Reilly et al., 2015). As other studies have emphasized, many of these studies fail to account for other potential variables, such as spatial ability, despite their emphasis on gender differences (Sharp et al., 2022; Wiesman & Wilson, 2019). Therefore, it is difficult to ascertain which factor (gender or spatial ability) has the greatest impact on multimedia learning.

Novelty dari penelitian ini terletak pada pendekatan holistiknya dalam mempertimbangkan faktor-faktor yang saling terkait, seperti gender, jenis multimedia, dan kemampuan spasial, serta dampaknya terhadap hasil pembelajaran. Penelitian sebelumnya cenderung fokus pada satu atau dua faktor saja, sedangkan penelitian ini menggabungkan ketiganya untuk memberikan pemahaman yang lebih komprehensif. The novelty of this study lies in its holistic approach in considering interrelated factors, such as gender, multimedia type, and spatial ability, as well as their impact on learning outcomes. Previous studies have tended to focus on just one or two factors, whereas this study combines all three to provide a more comprehensive understanding. The primary aim of this study is to examine the relationship between gender and the type of multimedia learning materials in relation to learning outcomes, while also considering the influence of spatial ability. One supplementary aim of this research was to investigate the distinct learning impact of retention and transfer, specifically in relation to gender and multimedia type. The second purpose of this study aims to rectify the disproportionate emphasis on assessing retention compared to transfer in multimedia learning. Retention refers to learners' capacity to recall, recognize, and reproduce taught knowledge, while transfer pertains to their ability to apply learned content to novel situations. This research study provides a distinctive contribution to the field by examining the influence of gender on the acquisition of scientific knowledge through the utilization of both two-dimensional (2D) and three-dimensional (3D) learning materials. Additionally, this study takes into account the potential confounding factor of spatial aptitude. The study has an equivalent number of male and female participants.

2. METHOD

This study used a multivariate quantitative approach. The independent variables (IV) in this study were gender and multimedia type (static and animation), and the covariate was spatial ability. The dependent variable (DV) to test the hypothesis was the learning outcome of science concepts measured through the implementation of learning evaluation. A total of 164 students majoring in elementary teacher education were involved in this study consisting of 82 males and 82 females who were selected using purposive sampling technique with the criteria of having learned the basic concepts of science, majoring in elementary education, and having taken at least one year of college (S. Berney & Bétrancourt, 2016; Creswell, 2017). Previous studies did not control the number of participants carefully so that it could affect the results of the study. The method of investigation employed in this study encompasses the utilization of two distinct learning tasks in conjunction with a spatial ability measurement tool. The selection of learning tasks was based on themes that are not typically addressed in informal learning environments. Furthermore, the articulation of information acquired from factual and conceptual knowledge can provide challenges, therefore prompting the selection of two learning tasks that specifically target factual and conceptual knowledge domains: the solar system and the human skeletal system. Given the limited empirical information pertaining to the impact of animation based on knowledge type, it was postulated that this particular selection would not exert a substantial influence on the outcomes of the investigation (S. Berney & Bétrancourt, 2016; Creswell, 2017). It was further assumed that the intended participants would have limited knowledge or experience regarding the above topics.

2D and 3D learning media are provided by the researcher and multimedia-related principles have been adopted when creating these learning media. In this study, the spatial proximity principle, cueing principle, modality principle, and temporal proximity principle have been adopted according to the supporting literature (Mayer & Estrella, 2014; Mayer & Pilegard, 2014; van Gog, 2014). The primary objective is ultimately subdivided into smaller parts in accordance with the idea of segmentation, which serves to effectively manage crucial cognitive processing. The impact of multimedia quality on learner motivation necessitates the application of these concepts to both static and animated media in an equitable manner. The visual and aural elements are identical, with the sole distinction being the static or moving nature of the visual component. Therefore, it was hypothesized that maintaining uniformity in the visual stimuli presented to both experimental groups would mitigate potential variations in affective responses. Each learning task was accompanied by ten questions. To measure spatial ability, a paper folding test was adopted from (French et al., 1963). The examination requires individuals to envision a sheet of paper that has undergone the process of folding, perforation, and subsequent unfolding. Subsequently, the examination prompts individuals to identify the accurate depiction of an unfolded image from a set of alternatives, based on the appropriate placement of perforations. The paper folding test is administered in two distinct sub-sections, wherein the questions are subjected to a timed format.

Based on the description of the objectives above, the problem solving approach of this study uses the hypothesis-driven problem solving type, as shown in Figure 1 (Gorriz et al., 2022). For the first hypothesis (H1), multivariate analysis of covariance (MANCOVA) was conducted using the Statistical Package for the Social Sciences (SPSS) version 27.0 application program. For the second hypothesis (H2), MANCOVA was conducted with repeated measures, using retention and transfer scores as within-subject variables, and gender and multimedia type as between-subject variables. In addition to these main data analyses, correlation tests were also conducted to test participants' prior knowledge of the learning task topics.

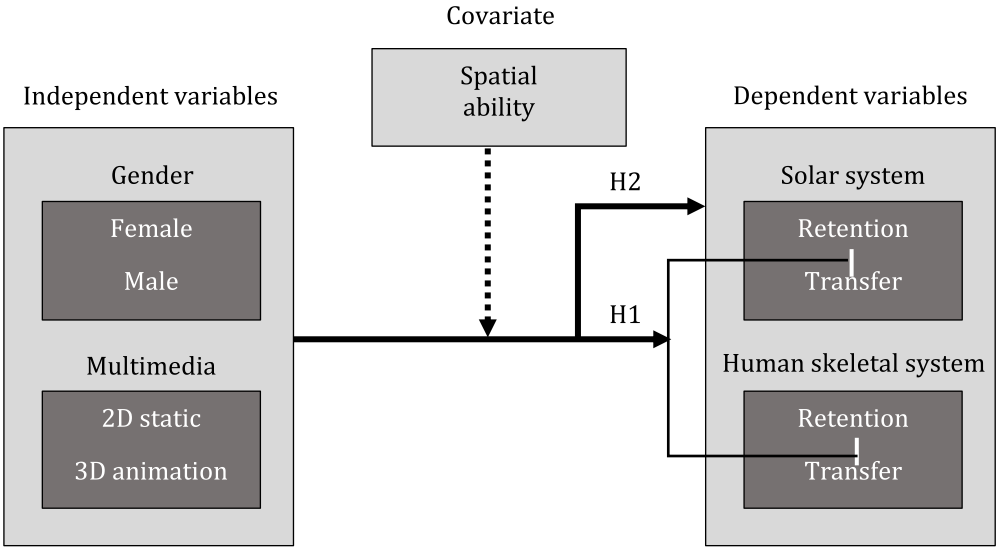

Figure 1. Relationship Between The Independent and Dependent Variables Along with Covariate.

3. RESULT AND DISCUSSION

Result

The assumptions necessary for conducting a Multivariate Analysis of Covariance (MANCOVA), including homogeneity of regression slopes and homoscedasticity, were thoroughly assessed and found to be met. These assumptions, in addition to those required for conducting Analysis of Variance (ANOVA) and Analysis of Covariance (ANCOVA), were carefully investigated and determined to be satisfied. The lack of statistical significance in Box's M can be attributed to the imbalanced nature of the study design. However, the trace statistic proposed by Pillai (referred to as Pillai V) was chosen for subsequent data analysis because to its superior robustness in handling departures from assumptions compared to other commonly used MANCOVA statistics. A single multivariate outlier was identified in the retention scores of the repeated measures MANCOVA analysis. Given the lack of evidence suggesting any undue effect exerted by this case, and the fulfillment of all other assumptions, it was deemed necessary to retain this case for further investigation. Further to hypothesis testing, descriptive statistics for the dependent variable investigated to gain a comprehensive understanding of learning outcomes can be seen in Table 1. All the instrument test were valid and reliable with Cronbach's alpha was 0.78.

For each task, Pearson correlation coefficients were calculated to examine the relationship between prior knowledge and learning outcomes. Table 2 shows No statistically significant correlation was found. Using spatial ability as a covariate, the main effect of gender was statistically significant with a small effect size(Pillai V = 0.080, F(2, 228) = 10.440, p 0.001, multivariate partial η^2 = 0.010). The covariate had a large effect size and was statistically significant (Pillai V = 0.341, F(2, 228) = 61.446, p < 0.001, multivariate partial η^2 = 0.309). In order to obtain a power of 0.95, the critical value for Pillai V in this analysis had to be equal to or greater than 0.060. Both the main effect of gender and the covariate of spatial ability significantly exceeded this critical value, ensuring that this analysis has a high level of power. The research found neither a main effect nor an interaction effect between multimedia type and gender. Having found a gender main effect after adjusting for spatial ability, H1 was adopted.

To investigate whether the gender primary impact findings were due to imbalanced groups based on gender, a second analysis was carried out with a gender-balanced subsample from which some female participants were randomly omitted. This subsample revealed statistical significance with a small to medium effect size for gender (Pillai V = 0.152, F(2, 97) = 8.722, p < 0.001, multivariate partial η^2 = 0.071) and significance with a large effect size for the covariate (Pillai V = 0.317, F(2, 98) = 22.684, p < 0.001, multivariate partial η^2 = 0.278). Table 3 provides a summary of the MANCOVA's findings.

Table 1. Descriptive Statistics For Hypothesis H1

IV	DV and CV	Mean	SD	Skew	Kurtosis
	Overall				
	Solar system score	6.284	1.582	-0.525	0.323
	Human skeletal system score	5.418	1.787	-0.062	-0.765
	Spatial ability	9.815	4.358	0.042	-0732

IV	DV and CV	Mean	SD	Skew	Kurtosis
		Gender			
Female	Solar system score	6.030	1.598	-0.474	0.275
	Human skeletal system score	5.289	1.752	0.023	-0.732
	Spatial ability	9.689	4.142	0.061	-0.558
Male	Solar system score	7.061	1.243	-0.381	-0.128
	Human skeletal system score	6.248	1.569	-0.415	-0.433
	Spatial ability	10.865	5.032	-0.178	-1.142
		Media Type			
2D static	Solar system score	6.239	1.540	-0.628	0.782
	Human skeletal system score	5.561	1.862	-0.093	-0.932
	Spatial ability	10.061	4.364	0.048	-0.677
3D animation	Solar system score	6.276	1.609	-0.0436	-0.047
	Human skeletal system score	5.465	1.711	-0.036	-0.542
	Spatial ability	9.761	4.368	0.035	-0.772

Following the first analysis, subsequent post hoc examinations revealed that the primary influence of gender, as well as the impact of the covariate, remained consistent across both learning tasks. The information is succinctly presented in Table 4. The analysis of mean scores indicated that male participants consistently outperformed their female counterparts on both learning tasks. After adjusting the means for spatial ability, it can be observed in Table 5 that the utilization of 3D animation learning resources led to an increase in women's scores, while the use of 2D static learning resources resulted in an increase in men's scores. Nevertheless, this observed trend did not achieve statistical significance.

Table 2. Correlations Between Prior Knowledge and Learning Outcomes

Prior knowledge	Overall	Retention	Transfer
Solar system	0.041	0.033	0.037
Human skeletal system	-0.071	-0.087	-0.030

Table 3. Multivariate Tests of Between-Subjects Effects for Hypothesis H1

IV and CV	Pillai *V*	*F*	*df*	Error *df*	p	Partial η^2
Gender	0.152	8.721	2	98	< 0.001	0.072
Media	0.013	0.673	2	98	0.512	0.006
Gender x Multimedia	0.011	0.553	2	98	0.577	0.011
Spatial ability	0.317	22.864	2	98	< 0.001	0.277

With spatial ability as a covariate, the main impact of test type (i.e., retention and transfer) demonstrated statistical significance and a sizable effect size (Pillai V = 0.898, F(2. 240) = 1066.423, p < 0.001, multivariate partial η^2 = 0.898). A minor impact size and statistical significance were found for the interaction between test type and gender (Pillai V = 0.029, F(2,.240) = 3.633, p < 0.028, multivariate partial η^2 = 0.029). The crucial value for Pillai V in this study had to be greater than or equal to 0.066 in order to reach a power of 0.95. Strong power in this analysis was ensured by the main effect of test type and the interaction effect of test type and gender both exceeding this crucial value. There were no other significant findings. H2 was accepted, however, as a result of the findings' substantial support for both the test type's main effect and its interaction effect with gender. Similar to the initial hypothesis, further examination was carried out utilizing the balanced sub-sample. The results obtained from this subset of data demonstrated statistical significance with a large effect size for the variable of test type (Pillai V = 0.902, F(2. 99) = 457.850, p < 0.001, multivariate partial η^2 = 0.902). Additionally, there was a significant finding with a medium effect size for the interaction between test type and gender (Pillai V = 0.088, F(2. 99) = 4.843, p < 0.010, multivariate partial η^2 = 0.088). Table 6 presents a summary of the repeated MANCOVA.

Table 4. Post Hoc Analyses for Hypothesis H_1

IV and CV	DV	Type III SS	*df*	MS	*F*	*p*
Gender	Solar system score	26.834	1	26.834	15.283	< 0.001
	Human skeletal system score	29.547	1	29.547	12.347	< 0.001
Spatial ability	Solar system score	161.027	1	161.027	91.742	< 0.001
	Human skeletal system score	169.143	1	169.143	70.642	< 0.001

Table 5. Comparison of Means: Before and After Controlling for Spatial Ability for Hypothesis H_1

Gender	Multimedia	DV[a]	Unadjusted			Adjusted		
			Mean	SE	*CI*	Mean	SE	*CI*
Female	2D static	S	6.084	0.162	(5.751, 6.411)	6.043	0.132	(5.782, 6.307)
		H	5.471	0.187	(5.101, 5.842)	5.431	0.157	(5.123, 5.739)
	3D animation	S	6.015	0.163	(5.693, 6.334)	6.142	0.136	(5.871, 6.413)
		H	5.108	0.168	(4.773, 5.433)	5.237	0.161	(4.932, 5.545)
Male	2D static	S	6.833	0.227	(6.364, 7.302)	6.861	0.261	(6.347, 7.371)
		H	5.912	0.375	(5.134, 6.692)	5.942	0.304	(5.340, 6.537)
	3D animation	S	7.288	0.256	(6.758, 7.821)	6.953	0.264	(6.432, 7.466)
		H	6.783	0.245	(6.277, 7.290)	6.446	0.308	(5.851, 7.053)

Note: [a] S = Solar system; H = Human skeletal system

Table 6. Repeated Measures Multivariate Tests to Examine The Between-Subjects Effects, Specifically Focusing on Hypothesis H_2

	Pillai *V*	*F*	*df*	Error *df*	*p*	Partial η^2
TType[a]	0.902	457.850	2	99	< 0.001	0.902
TType x Gender	0.088	4.843	2	99	0.010	0.088
TType x Multimedia	0.008	0.387	2	99	0.682	0.008
TType x Gender x Multimedia	0.012	0.558	2	99	0.573	0.011

Note: [a] TType (test type): retention or transfer learning

Table 7. Post-Hoc Analyses for Hypothesis H_2

DV		Type III SS	*df*	MS	*F*	Partial η^2
TType[a]	Solar system score	898.134	1	898.134	1919.397	<0.001
	Human skeletal system score	209.083	1	209.083	262.365	<0.001
TType x Gender	Solar system score	0.005	1	0.005	0.010	0.922
	Human skeletal system score	5.797	1	5.797	7.272	0.008

Note: [a] TType (test type): transfer learning or retention learning

Significant differences were seen between retention and transfer of learning across both learning tasks, as shown by post hoc analysis can be seen in Table 7. Upon further analysis of the adjusted averages presented in Table 8, it was seen that the retention of learning exhibited a statistically significant increase in both learning tasks. The study observed a drop in learning results from retention to transfer for both female and male participants. Specifically, the learning outcomes for females in the solar system task were 2.705, while for the human skeletal system task they were 1.408. Similarly, the learning outcomes for males in the solar system task were 2.718, while for the human skeletal system task they were 0.931. However, it is noteworthy that the decline in learning outcomes was substantially less pronounced for male participants in the human skeletal system task.

Table 8. Adjusted Means for Retention Learning and Transfer of Learning for Hypothesis H_2

DV	TType[a]	IV		Mean	SD	Skew	Kurtosis
Solar system score	Retention	(Total)[b]		4.487	0.944	-1.211	2.108
		Gender	Female	4.398	0.062	4.278	4.517
			Male	4.814	0.118	4.582	5.041
		Multimedia	2D	4.438	0.077	4.291	4.587
			3D	4.534	0.076	4.383	4.687
	Transfer	(Total)[b]		1.776	0.908	0.107	-0.563
		Gender	Female	1.692	0.056	1.581	1.806
			Male	2.092	0.112	1.872	2.312
		Multimedia	2D	1.777	0.073	1.638	1.921
			3D	1.776	0.074	1.634	1.922
Human skeletal system score	Retention	(Total)[b]		3.413	1.082	-0.225	-0.517
		Gender	Female	3.372	0.074	3.224	3.521
			Male	3.561	0.145	3.272	3.847
		Multimedia	2D	3.436	0.092	3.251	3.621
			3D	3.386	0.094	3.198	3.576

DV	TType[a]	IV		Mean	SD	Skew	Kurtosis
	Transfer	(Total)[b]		2.106	1.112	0.084	-0.952
		Gender	Female	1.964	0.065	1.831	2.095
			Male	2.631	0.132	2.372	2.887
		Multimedia	2D	2.102	0.086	1.936	2.268
			3D	2.105	0.084	1.937	2.272

Note: [a] TType (test type): transfer learning or retention learning; [b] The compilation of statistics does not rely on adjusted means

Discussion

The current study aimed to examine the possible correlation between gender, type of multimedia learning resource, and learning outcomes, while also considering the impact of spatial ability (H1). Furthermore, the study investigated if there were varying effects on the retention and transfer of learning, taking into account the influence of spatial ability, with regards to gender and multimedia type (H2). One of the primary findings drawn from this investigation is that, even after accounting for spatial ability, males exhibited superior performance compared to girls in multimedia learning tasks (H1) from both of solar system and human skeletal system materials, as shown in Table 1. Similar research explained that this situation can be happened because after graduating from high school, for all combinations of test scores, boys were significantly more likely than girls to choose competitive preparatory classes in science (Landaud et al., 2020; Rapoport & Thibout, 2018). One perspective suggests that the observed gender effect can be explained by the temporal constraints inherent in the spatial ability assessment employed in this study. As stated in previous research findings that the application of time limits to the assessment of spatial abilities can have a negative impact on women's spatial abilities (Harris et al., 2021; Ramírez-Uclés & Ramírez-Uclés, 2020). Therefore, it is possible that spatial ability was not consistently accounted for across genders, and the observed gender impact may really be attributed to spatial ability. Conversely, it is plausible that a gender impact does exist and is associated with intrinsic gender disparities in the processing of multimedia learning materials, presumably attributable to a range of factors including socio-cultural influenceswond (Friedman-Sokuler & Justman, 2020; Wondimu, 2022). The study focused on themes that are commonly encountered in daily life. However, it is possible that these topics elicited varying degrees of interest among various genders, presumably impacted by socio-cultural practices. These differences in interest may have contributed to variations in learning outcomes. Future studies should focus on the exploration and objective delineation of distinct gender disparities.

The study's findings regarding the limited impact of multimedia type on learning outcomes (H1) present a possibility for further examination of the extent to which existing literature on the effects of multimedia resource type adequately addresses the targeted outcomes. Meta-analysis reveals that 3D animated multimedia has been found to result in more favorable learning results (S. Berney & Bétrancourt, 2016; Ploetzner et al., 2020). However, it is important to note that a significant majority of the research included in their analysis did not demonstrate any discernible changes in learning outcomes between animated and static resources. Considering the significant impact of spatial ability in this investigation and the disparity highlighted in meta-analysis, it is plausible to suggest that the variations in science learning outcomes reported in existing studies may not solely be attributed to the type of multimedia utilized. These changes may also be indicative of the impact of additional moderating factors, such as individual differences affective states, emotional experiences, motivational factors, and metacognitive processes (Harefa & Huang, 2023; Kryshko et al., 2022; Lindner et al., 2021; Stark et al., 2018; Y. Wang et al., 2023). Further investigation is required to thoroughly analyze the variables that could potentially alleviate the impact of multimedia format on educational achievements. In a similar vein, the present study revealed contrasting patterns wherein female scores exhibited an upward trajectory in the 3D animation group, whereas male scores displayed an upward trajectory in the 2D static group, after the means were adjusted for spatial ability, as shown in Table 5, Table 6, and Table 8. The observed trends align with existing literature indicating that females tend to derive greater benefits from 3D animated resources in solar system and human skeletal system topics. The cognitive load required to comprehend animation would be greater in comparison to static images. Based on our research, it appears that, on average, females process verbal information more efficiently than males. Furthermore, they require less mental effort to process verbal information, which frees up cognitive resources for the processing of spatial information. As a result, females exhibit greater proficiency in processing dynamic images, such as 3D animations, in comparison to males, due to their greater allocation of cognitive resources towards comprehending visuospatial information .

The primary result pertaining to the impact of test type, specifically retention and transfer of learning, indicates that there was a notable decrease in learning outcomes from retention to transfer. This decrease was substantially less pronounced for males in the human skeletal system task, as indicated by hypothesis H2. Several learning models, such as Bloom's taxonomy, Webb's depth of knowledge, and the

Structure of observable learning outcomes taxonomy, advocate for the concept of providing increasingly challenging learning materials to gradually enhance the cognitive demands placed on learners. Drawing upon the principles of these learning models, it may be postulated that the process of transferring knowledge necessitates a greater allocation of cognitive resources compared to the act of retaining information. The aforementioned premise is validated, since the scores of transferred students were definitely shown to be lower in comparison to the scores of students who remained at the same educational institution. The variation in the decline observed between genders in the human skeletal system task may be attributed to differences in the learning topics, which could have resulted in varying levels of interest. This discrepancy in interest may be influenced by socio-cultural norms, as highlighted in the study of on gender stereotypes in education (Brown & Stone, 2016; Kollmayer et al., 2018). The inclusion of both gender-neutral and gender-specific issues in future studies, taking into account socio-cultural norms, could potentially provide more comprehensive insights into the impact of science subject matter on learning outcomes when using multimedia.

The findings from Table 7 and Table 8 that the type of multimedia used did not have an impact on the decline in learning outcomes from retention to transfer (H2), even after accounting for spatial ability, suggests that the cognitive demands imposed by the transfer questions may have been too challenging for any specific type of multimedia to offset. There is a possibility that both types of multimedia effectively reduced cognitive burden in a similar manner during the activities, leading to no noticeable changes in learning outcomes, but both of 2D static and 3D animation can be use to reconstruct the science concept for university students. However, (Hammoumi et al., 2022; Teplá et al., 2022) aggred that indicate that incorporating 3D model animations into instruction learning substantially enhanced students' intrinsic motivation to learn natural sciences (more precisely, its constituent parts: a) interest; b) effort to actively engage in the process of learning; c) perceived competence; and d) comprehension of the subject's practicality.

This research has important implications in understanding differences in learning outcomes between genders in the context of the use of multimedia in science learning, as well as implications in helping to develop learning strategies that are more effective in utilizing multimedia in science education. A limitation of this study is that focusing on specific gender contexts and sample sizes that may limit the generalizability of findings, the study also faces limitations in considering additional factors that can affect learning outcomes, such as learning motivation, previous technological experience, and psychological factors. Based on the limitations identified, it is recommended that future studies expand the scope of the sample and consider additional factors that may affect learning outcomes. In addition, further research can also focus on a more in-depth analysis of the impact of multimedia types on learning outcomes, taking into account moderating factors that might influence the relationship.

4. CONCLUSION

This study reveals that female scores exhibited an upward trajectory in the 3D animation group, whereas male scores displayed an upward trajectory in the 2D static group when learning solar system and human skeleton system topics. Both multimedia can be used to reconstruct male and female students' comprehension of science concept in both transfer and retention learning. Moreover, this study provides further evidence supporting the notion that spatial ability plays a substantial role in the acquisition of knowledge through the utilization of 2D static and 3D animation multimedia. Given the significance of spatial ability in the context of multimedia learning, a considerable amount of research in recent years has focused on developing strategies to help students improve their spatial abilities. Illustrations of pragmatic methodologies encompass the utilization of visual stimuli and spatial methods for recording information. Therefore, it is advisable to conduct further study in order to thoroughly examine the benefits of different techniques aimed at improving spatial ability. However, in the meanwhile, tactics that have already shown positive results might be implemented in educational settings.

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