https://journal.akademimerdeka.com/ojs/index.php/jees/index

JEES Journal of Education and Educational Sciences

JEES | e–ISSN 3089-1329 | Vol. 2 No. 2. (2026)

Research Article

The Effect of the Snowball Drilling-Based Jigsaw Model on Learning Independence and Mathematical Spatial Ability of Elementary School Students

Ike Kurniawati[1]
Universitas Bengkulu, Indonesia
ikekurniawati@unib.ac.id

Herlin Kurniasari[2]
Universitas Negeri Yogyakarta, Indonesia
herlinkurniasari.2024.student@uny.ac.id

Abstract: This study aims to determine the influence of variables in the snowball drilling-based Jigsaw learning model. The research method employed a pre-experimental design using a one-group pretest–posttest design. The research subjects were school students with a saturated sampling technique and a sample size of 60 respondents. The research instruments consisted of a cognitive test of mathematical spatial ability and a questionnaire on students' mathematical learning independence as well as a questionnaire on responses to the Jigsaw learning model. Data analysis techniques used multiple linear regression tests to determine the effect of the snowball drilling-based Jigsaw model on students' learning independence and mathematical spatial ability. Path analysis was used to test the relationship between aspects of independence and mathematical spatial ability. The results showed that the application of the snowball drilling-based Jigsaw model had a significant effect ($p < 0.05$) on improving elementary school students' mathematical learning independence and mathematical spatial ability. This study contributes novelty by integrating the Jigsaw cooperative model with Snowball Drilling to simultaneously strengthen students' learning independence and mathematical spatial ability at the elementary level, an area that has been rarely examined in previous studies. In addition, there is a positive relationship between aspects of the variables of learning independence and mathematical spatial ability, as can be seen from the p-value < 0.05. The Jigsaw model can encourage students to increase their learning independence through responsibility and develop mathematical spatial abilities through understanding relationships, perception, visualization, rotation, and spatial orientation. Thus, this study can be used as a reference in similar studies.

Keywords: cooperative learning model, jigsaw model of independent learning, mathematical spatial

Corresponding Author:
Ike Kurniawati
ikekurniawati@unib.ac.idm

How to Cite: Kurniawati, I., & Kurniasari, H. (2026). The Effect of the Snowball Drilling-Based Jigsaw Model on Learning Independence and Mathematical Spatial Ability of Elementary School Students. *JEES: Journal of Education and Educational Sciences*, 2(2), 40-54. https://doi.org/10.70152/jees.v2i2.322

Article submitted 2026-01-08. **Revision uploaded** 2026-01-13. **Final acceptance** 2026-01-14.

Copyright © **2026** by the authors of this article. Published under CC-BY.

This is an **open access** article OPEN ACCESS

INTRODUCTION

A learning model is a conceptual framework used as a guideline in designing and implementing the teaching and learning process. This model contains systematic steps, strategies, approaches, and techniques that help teachers achieve learning objectives effectively (Masruri, 2022). In other words, learning models serve as patterns that can be used to regulate interactions between teachers and students, lesson materials, and the learning environment to create an active, creative, and meaningful learning atmosphere (Khoerunnisa & Aqwal, 2020). In mathematics learning, there are many innovative models that can be applied, including contextual learning models, direct learning models, cooperative learning models, Problem Based Learning models, Project Based Learning models, Inquiry Learning, and Discovery Learning (Pane, 2023). One of the cooperative learning models, namely the snowball drilling-based Jigsaw learning model, directs students to hone their critical thinking skills through interaction in small groups (Khulqi, Hanifah, & Sunaengsih, 2024).

Based on observations in elementary schools, the low level of student learning independence has an average of 52.96%. Based on this data, it shows that the low level of student learning independence is caused by a lack of understanding of mathematics and students' perception that mathematics is difficult. Therefore, educators need to improve learning independence by applying appropriate learning models and methods, using learning media that is easy to understand, and then conducting evaluations (Sulistiarini, Marmoah, & Sriyanto, 2023). Independent learning is very necessary, especially in mathematical spatial abilities, particularly in understanding geometric concepts, visualizing two- and three-dimensional shapes, and mathematical forms independently (Nurhayati & Handayani, 2020). The low level of students' mathematical spatial abilities is due to the fact that mathematics requires a deep understanding, especially in story problems in materials that require reasoning about the visualization of dimensional shapes, for example, geometry (Yulia & Amanda Putri, 2024).

Students have problems with mathematical spatial abilities or mathematical thinking that are still very low. This situation is evidenced by the initial results, which show the lowest score of 32.14 and the highest score of 78.57, with an average of 43.57. Based on the results of the mathematical spatial ability test for fifth-grade students, the Final Completion Limit (BTA) was 45.93, resulting in 10 students passing the BTA with a presentation of 33% and 20 students failing the BTA with a presentation of 67%. Students' learning independence and spatial abilities can be improved through the application of effective learning models so that students can play an active role during the learning process, one of which is the Jigsaw learning model (Iskandar & Badruzzaman, 2017). The Jigsaw learning model is a learning model that emphasizes the importance of cooperation among students in small learning groups (Khulqi et al., 2024). In the Jigsaw learning process, students are divided into two types of groups, namely core groups and expert groups, where each student has their own role (Shoffa & Suprapti, 2017).

Although previous studies have reported that the Jigsaw model can improve student interaction and learning outcomes (Iskandar & Badruzzaman, 2017; Khulqi et al., 2024), most existing research examines Jigsaw or Snowball Drilling as separate instructional approaches. Limited studies have explored the integrated application of Jigsaw combined with Snowball Drilling, particularly in relation to students' learning independence and mathematical spatial ability at the elementary school level. The Jigsaw learning model involves groups of experts who are responsible for mastering the material presented by the teacher and then explaining it to their original groups, which helps students understand the material more deeply and independently. This aims to increase student independence during the mathematics learning process in the classroom (Pertiwi & Amaliyah, 2024).

This research is important because the application of the snowball drilling-based Jigsaw model can foster student independence in learning through individual responsibility and group discussion while strengthening memory through systematic repetition. Its urgency lies in the need to improve mathematical spatial abilities, particularly in flat-sided spatial figures that require visualization, mental rotation, spatial orientation, and inter-object relationships, while in the field, students still have difficulty understanding geometric concepts due to conventional learning methods that do little to encourage independent learning. Therefore, this study aims to analyze the effect of the snowball drilling-based Jigsaw model on elementary school students' learning independence and mathematical spatial abilities, as well as to examine the relationship between aspects of these two variables, as well as to examine the relationship between aspects of these two variables so that it can contribute to the development of mathematics learning models in elementary schools.

THEORETICAL FRAMEWORK

Jigsaw Learning Model Based on Snowball Drilling

The Jigsaw learning model is a form of cooperative learning that emphasizes individual responsibility and positive interdependence among students in understanding learning materials. Students learn specific parts of the material in their home groups, then are responsible for explaining that material to other group members, so knowledge is constructed thru social interaction and group discussion (Shoffa & Suprapti, 2017). This activity encourages students' active involvement in the learning process and develops critical thinking skills thru the exchange of ideas in small groups (Khulqi et al., 2024). The main characteristic of the Jigsaw model lies in the direct involvement of students in various roles during learning. Students work in heterogeneous groups of four to five members with different task assignments so that each student has the opportunity to contribute to understanding and conveying the material.

This process strengthens students' sense of academic responsibility, self-confidence, and communication skills thru discussion and group collaboration (Siswanto Pertiwi & Amaliyah, 2024). The Jigsaw learning syntax begins with the formation of home groups, in-depth study of the material in expert groups, returning students to their home groups to teach each other the material, and individual evaluation, the results of which are accumulated as a group score (Sukarmini et al., 2016). This stage shows that Jigsaw learning systematically integrates cognitive, social, and evaluative processes. This model has advantages in increasing student motivation, activity, and cooperation, although it requires optimal classroom management to address differences in student character and participation levels (Abdullah, 2017). The Snowball Drilling approach is a method of learning based on repeated practice aimed at strengthening conceptual understanding thru continuous problem-solving. This method encourages students to master the material in depth thru systematic and intensive practice (Mardiana, 2022).

Snowball Drilling is conducted by alternately calling on students or groups to answer questions, creating an active and challenging learning environment (Syafitri et al., 2021). Repeated practice is considered effective in strengthening the mastery of mathematical concepts that require accuracy and consistency of understanding (Suprijono in Hartono, 2018). The integration of the Snowball Drilling-based Jigsaw model combines the benefits of group collaboration with concept reinforcement thru structured exercises. Learning begins with group discussions to build conceptual understanding, which is then strengthened thru Snowball Drilling as a form of continuous evaluation that demands individual and group responsibility. This pattern encourages students to learn independently and collaboratively, minimizing the weaknesses of the Jigsaw model thru directed practice (Windi et al., 2024).

Independent Learning

Learning independence is the ability of students to manage their learning process independently, including planning, implementation, monitoring, and evaluation of learning. Learning independence reflects students' internal drive to be proactive, responsible, and not dependent on others in completing learning tasks (Guntur et al., 2017). This ability requires students to organize themselves, control their learning process, and independently assess their learning outcomes (Hamsina et al., 2023). Independent learning is characterized by self-confidence, discipline, responsibility, and the ability to view difficulties as challenges. Students with high learning independence tend to actively seek information, are brave in expressing their opinions, and consistently complete tasks without excessive dependence on teachers or peers (Indah & Farida, 2021).

Learning independence is influenced by internal factors such as motivation, self-confidence, and study habits, as well as external factors such as the learning environment, the role of the teacher, and the teaching methods used (Laili, 2021). Jigsaw and Snowball Drilling-based cooperative learning has the potential to strengthen learning independence thru active student involvement, division of responsibility within groups, and continuous independent practice. The indicators of learning independence in this study include freedom to be responsible, a progressive and persistent attitude, initiative and creativity, self-control, and confidence in one's own abilities (Widuroyekti in Rusmini et al., 2024).

Mathematical Spatial Ability

Mathematical spatial ability is a cognitive ability related to visual representation and spatial reasoning in the context of mathematics. This ability allows students to imagine, rotate, construct, and analyze geometric objects, thus facilitating the solution of mathematical problems (Nurhayati & Handayani, 2020). Mastering spatial abilities is important because many mathematical concepts are abstract and require spatial visualization for optimal understanding (Wulansari & Adirakasiwi, 2019). Mathematical spatial ability encompasses indicators of spatial perception, visualization, mental rotation, spatial relationships, and spatial orientation. Spatial perception relates to the ability to observe the position of objects. Visualization relates to the ability to change and represent the shapes of flat and three-dimensional figures. Mental rotation reflects the ability to accurately rotate two- and three-dimensional objects. Spatial relationships demonstrate an understanding of the interconnectedness between different parts of an object. Spatial orientation relates to the ability to identify the shape and position of objects from various perspectives (I. Ningsih, 2019).

The Snowball Drilling-based Jigsaw model encourages students to actively visualize concepts, explain spatial representations to their peers, and reinforce understanding thru repeated practice. Theoretically, this process supports the improvement of elementary school students' mathematical spatial abilities. The Snowball Drilling-based Jigsaw model is theoretically expected to influence students' learning independence and mathematical spatial ability through three interconnected mechanisms: (1) individual responsibility embedded in the Jigsaw structure, (2) collaborative knowledge construction through expert and home group discussions, and (3) reinforcement of conceptual understanding through repeated Snowball Drilling practice. These mechanisms jointly support students' self-regulation, persistence, and spatial reasoning development, thereby strengthening both learning independence and mathematical spatial ability. Cooperative learning encourages student responsibility and active participation, while repeated practice reinforces understanding of mathematical concepts. Group interaction, discussion, and continuous evaluation create a learning environment that simultaneously supports the development of learning independence and mathematical spatial abilities.

METHODS

Research Design

This study employed a quantitative pre-experimental research method using a one-group pretest–posttest design. The absence of a control group indicates that causal interpretations are limited to observed changes before and after treatment. This design was used to examine the effect of the applied learning model on students' mathematical spatial ability and learning independence. In this approach, measurements were conducted before and after the implementation of the learning model to identify changes resulting from the treatment.

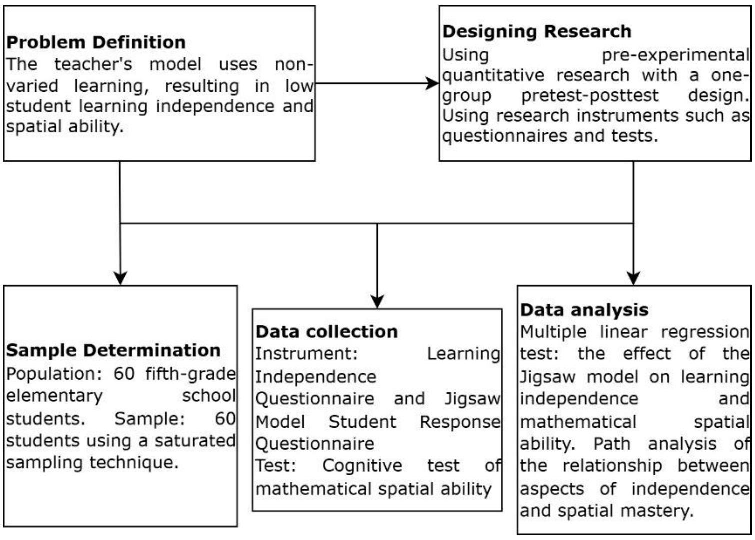

Figure 1. Research Procedures

Sample

The research subjects consisted of fifth-grade elementary school students. A saturated sampling technique was used, in which all members of the population were included as the research sample. The total number of respondents involved in this study was 60 students.

Data Collection

Data were collected using two types of research instruments. The mathematical spatial ability test and learning independence questionnaire were developed based on established indicators from previous studies (Nurhayati & Handayani, 2020; Widuroyekti in Rusmini et al., 2024). Instrument validity was examined through expert judgment, and reliability testing showed acceptable internal consistency (Cronbach's alpha > 0.70). The first instrument was a mathematical spatial ability test, which was used to measure students' spatial skills. The second instrument was a mathematical learning independence questionnaire, designed assess students' independence in learning mathematics. Both instruments were administered to obtain quantitative data relevant to the research variables.

Data Analysis

The data analysis technique employed in this study was multiple linear regression analysis, which was used to examine the effect of the learning model on students' learning independence and mathematical spatial ability. In addition, path analysis was conducted using the SmartPLS 3.0 application to determine the relationships among the aspects within each research variable. The research procedures were arranged systematically based on the predetermined data analysis techniques, and the overall flow of the research implementation was illustrated in a research procedure chart.

RESULT

The first activity carried out was a pretest in the form of a questionnaire. The questionnaire had undergone instrument testing, which was given to fifth-grade students with a predetermined sample size of 60 respondents. This section will describe the data obtained from the measurement of the Jigsaw Model variable (X) and the variables of Mathematics Learning Independence (Y1) and Mathematical Spatial Ability (Y2).

Table 1. Descriptive Data Test Results

Data		N	Mean	Median	SD	Min	Max
Learning Independence	Pretest TPS Model	60	61.85	61.00	10.010	40	86
	Posttest TPS Model	60	74.52	74.00	9.412	55	91
Mathematical Spatial Ability	Pretest TPS Model	60	46.50	45.00	7.892	30	65
	Posttest TPS Model	60	75.85	75.00	10.892	53	93
Jigsaw Model Response Questionnaire		60	75.88	75.00	9.951	53	97

Based on the descriptive analysis, the mean score of learning independence increased from 61.85 (SD = 10.01) in the pretest to 74.52 (SD = 9.41) in the posttest. Similarly, the mean score of mathematical spatial ability increased from 46.50 (SD = 7.89) to 75.85 (SD = 10.89). This section reports statistical outcomes without interpretative explanations, which are discussed in the following section. A similar pattern was also seen in mathematical spatial abilities, which developed better after the treatment was given. In addition, the results of the student response questionnaire regarding the application of the Jigsaw model showed positive responses, so it can be concluded that this learning model is not only able to improve cognitive aspects but is also supported by good learning independence among students. This test used multiple linear regression. The aim was to determine the effect of the snowball drilling-based Jigsaw learning model on students' mathematical learning independence. This can be seen in the table below.

Table 2. Multiple Linear Regression Test on Learning Independence

Coefficiens [a]						
Model		Unstandardized Coeffients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.187	2.978		-.063	.950
	Jigsaw Model	.989	.039	.957	25.267	.000

Dependent Variable: Learning Independence

Based on the table above, it can be seen that the significance value in the Jigsaw model for learning independence is 0.000 < 0.05. This shows that the use of the snowball drilling-based Jigsaw model has a significant effect on students' mathematical learning independence. Thus, it can be concluded that this learning model has an effect on improving students' learning independence in the mathematics learning process. The regression test of the snowball drilling-based Jigsaw learning model on mathematical spatial ability can be seen in the following table:

Table 3. Multiple Linear Regression Test on Spatial Ability

Coefficiens [a]						
Model		Unstandardized Coeffients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	7.089	.612		11.585	.000
	Jigsaw Model	.909	.008	.998	113.070	.000

Dependent Variable: Spatial Ability

Based on the table above, it can be seen that the significance value in the Jigsaw model on mathematical spatial ability is 0.000 < 0.05. This indicates that the use of the snowball drilling-based Jigsaw model has a significant effect on the mathematical spatial ability of elementary school students. Thus, it can be concluded that this learning model is effective in improving the mathematical spatial ability of elementary school students in the mathematics learning process. The relationship between the aspects of learning independence and the mathematical spatial ability of elementary school students can be tested using SmartPLS 3.0. This relationship shows that aspects of learning independence such as responsibility, progressiveness and persistence, initiative and creativity, and self-control contribute positively to students' mathematical spatial abilities. The results of the relationship between aspects of learning independence are presented in the following figure.

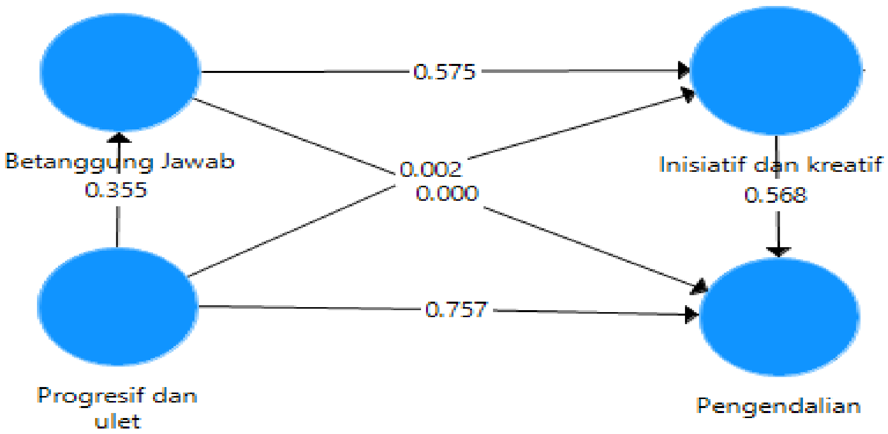

Figure 2. Results of the Learning Independence Correlation Test

Based on the figure above, there is a positive relationship between aspects of learning independence. These aspects are interrelated in the learning process. The relationship in this aspect can be seen more clearly in the following table.

Table 4. Results of the Learning Independence Correlation Test

Aspect	Original Sample	Sample Mean	SD	T Statistik	P Values	Description
Responsible → self-control	0.443	0.439	0.094	4.685	0.000	Accepted
Progressive → initiative	0.885	0.686	0.291	3.04	0.002	Accepted
Responsible → Progressive	0.121	0.093	0.131	0.926	0.355	Rejected
Responsible→ Initiative	0.149	0.171	0.261	0.571	0.568	Rejected
Initiative → self-control	0.044	0.042	0.079	0.561	0.575	Rejected
Progressive → control	-0.088	-0.039	0.284	0.31	0.757	Rejected

Based on the table above, in terms of learning independence, responsibility is related to the aspects of self-control and self-placement with a p-value of 0.000 < 0.05. Other related aspects of learning independence are aspect 2, progressive and persistent, and aspect 3, initiative and creativity, with a p-value of 0.002 < 0.05. Meanwhile, the other aspects of learning independence have p-values > 0.05, indicating that these aspects of learning independence are not statistically related. The relationship between the aspects of mathematical spatial ability is as follows.

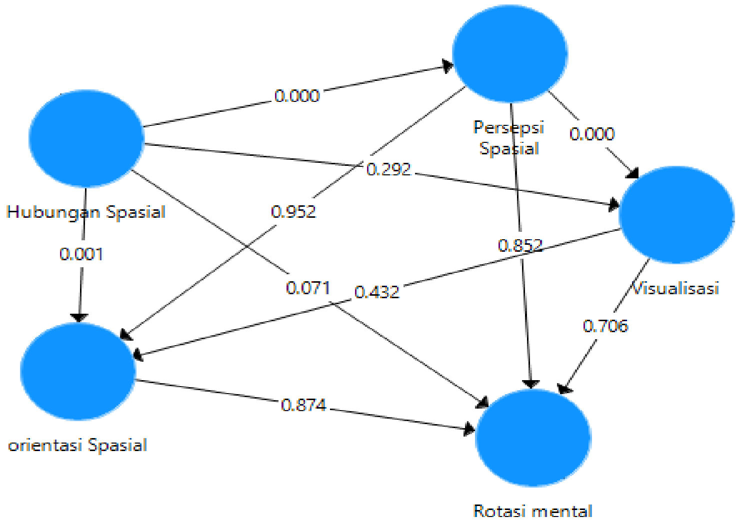

Figure 3. Results of Mathematical Spatial Correlation Tests

Based on the figure above, there is a positive relationship between aspects of mathematical spatial ability. These aspects are interrelated in the learning process. The relationship in this aspect can be seen more clearly in the following table.

Table 5. Results of Mathematical Spatial Correlation Test

Aspect	Original Sample	Sample Mean	SD	T Statistik	P Values	Description
Relationship→Spatial Perception	0.402	0.396	0.107	3.747	0.000	Accepted
Perception→Visualization	0.353	0.363	0.099	3.553	0.000	Accepted
Relationship→Spatial Orientation	0.447	0.457	0.136	3.283	0.001	Accepted
Relationship→Mental Rotation	0.283	0.272	0.157	1.808	0.071	Rejected
Relationship→Spatial Visualization	0.144	0.143	0.137	1.054	0.292	Rejected
Visualization→Spatial Orientation	-0.141	-0.134	0.179	0.786	0.432	Rejected
Visualization→Mental Rotation	0.065	0.069	0.173	0.377	0.706	Rejected
Perception→Mental Rotation	0.029	0.026	0.154	0.186	0.852	Rejected
Orientation→Mental Rotation	-0.025	-0.000	0.154	0.159	0.874	Rejected
Perception→Spatial Orientation	0.009	-0.003	0.141	0.061	0.952	Rejected

Based on the table above, in terms of mathematical spatial ability, aspect 4 spatial relationships is related to aspect 1 spatial perception. Then, aspect 1 spatial perception is directly related to spatial visualization, and aspect 4 spatial relationships is directly related to aspect 5 spatial orientation. Based on this explanation, these aspects are related because the p-value is 0.000 < 0.05. Meanwhile, the other aspects of learning independence have a p-value > 0.05, which indicates that these aspects of learning independence are not statistically related.

DISCUSSION

Based on the findings in the field, the Jigsaw learning model provides opportunities for students to be more active and independent during the learning process. This model creates learning conditions that are oriented towards independence, not dependence. Students do not only receive information, but also become active participants in the formation of knowledge (Arrahmah, Kusuma, & Fadhilaturrahmi, 2024). The findings indicate that the snowball drilling-based Jigsaw model is associated with improvements in students' learning independence and mathematical spatial ability. However, not all aspects of learning independence and spatial ability were significantly related, suggesting that contextual, developmental, and instructional factors may influence how these constructs interact at the elementary school level.

The results of multiple linear regression tests show a strong relationship between the use of this model and an increase in students' learning independence and mathematical spatial abilities. Similar research results were found in a study by Ningsih et al. (2014), which showed that cooperative learning and snowball drilling models were significantly and positively correlated with student learning independence. In line with the results of research by Saniatullaila et al. (2024), the Jigsaw model has an effect on learning independence. Similarly, research by Ranti et al. (2017) shows that learning independence has a significant effect on student learning outcomes. The application of the snowball drilling-based cooperative learning model can increase students' initiative in completing tasks independently and enhance their sense of responsibility for the learning process (Puspaningtyas, Prasetyo, & Farahsanti, 2021).

In line with Kusmayadi's (2022) cooperative learning, which explains that cooperative learning can increase positive interactions between students, thereby supporting the growth of self-confidence and independence. Based on multiple linear regression testing, the Jigsaw model affects students' mathematical spatial abilities. This is in line with the research by Ahmad et al. (2017), which found that the Jigsaw model is equivalent to group investigation in spatial achievement, but statistically there is no significant difference between the two models. Similarly, Masyhudi's (2023) research found that the Jigsaw model can increase learning activities in mathematics. In line with the research by Ahmad, Usodo, & Riyadi, (2017), in the GI cooperative learning model, jigsaw II, and direct learning, students with spatial abilities and good mathematics learning achievements.

In line with the research by Negara et al. (2015), the jigsaw learning model with or without CTL is superior to direct learning, but not statistically significant in terms of spatial ability. Based on the findings in the field, students who have good learning independence tend to be faster and easier in understanding mathematical spatial abilities, especially in flat-sided spatial figures. Students who are initiative, responsible, and able to control themselves in learning appear to be more active in exploring the shapes of solid figures, visualizing, and understanding the relationships and orientation of objects in space. This shows that aspects of learning independence contribute positively to the overall development of students' spatial abilities. Based on the results of the correlation test, it shows that every aspect of independent learning and mathematical spatial abilities are interrelated in the process of learning mathematics in elementary school.

It appears that responsibility is related to progressiveness and persistence, which build initiative, creativity, and self-control during the mathematics learning process. This is a very important basis in helping students deal with mathematics material that requires independent spatial understanding, such as flat-sided shapes (Kurniasih, 2017). In line with the results of learning independence, in every aspect of mathematical spatial ability, it was found that spatial relationships are related to spatial perception. Spatial perception is related to spatial visualization, and spatial relationships are also directly related to spatial orientation. This means that students who have the ability to understand spatial relationships tend to have good spatial perception, making it easier for them to visualize objects and understand orientation in space.

However, not all spatial aspects are significantly related to each other, indicating the role of other factors such as learning independence in supporting students' mathematical spatial abilities. These results are in line with the research by Hafidzah et al., (2021), which found that independent learning has a positive relationship with students' mathematical problem-solving abilities, including in solving spatial problems. Similarly, research by Fajri & Amir, (2022) shows that students' self-control and responsibility during learning contribute to improving their mathematical spatial abilities. Meanwhile, the results of the study by Ma'Rifatin et al. (2019) emphasize the importance of spatial visualization and spatial perception in solving mathematical problems, which is aided by high learning initiative. The results of this study are in line with Tusaadia et al. (2022), which shows that a meta-analysis found that learning independence is significantly related.

Mathematical learning independence at all levels of education is significantly related. This shows that mathematical learning that fosters student responsibility and initiative will have an impact on improving learning outcomes. Mathematical spatial abilities in this study show that students with a high level of learning independence will find it easier to develop their mathematical spatial abilities, especially in flat-sided spatial figures. In line with the research by Husni Sabil et al. (2024), it shows that spatial ability is closely related to cognitive style. The results of this study also show that not all indicators have a significant direct relationship, but they complement each other in forming optimal learning independence and mathematical spatial abilities in students. The aspects of learning independence and mathematical spatial abilities are not significantly related. However, each aspect has its own role in supporting students' mathematics learning process. These aspects complement each other in shaping students' learning independence so that they can learn independently and understand mathematics material better.

CONCLUSION

The snowball drilling-based Jigsaw learning model affects elementary school students' mathematical learning independence and mathematical spatial abilities. Based on path analysis, not all aspects of learning independence and mathematical spatial abilities are significantly related. In learning independence, responsibility and progressiveness support initiative and self-control, while in spatial ability, spatial relationships form the basis for perception, visualization, and spatial orientation. The Jigsaw model can encourage students to increase their learning independence through responsibility and develop mathematical spatial abilities through understanding spatial relationships, perception, visualization, rotation, and spatial orientation. Thus, this study can be used as a reference for teachers in implementing cooperative learning strategies that foster learning independence and spatial reasoning. Future research is recommended to employ experimental designs with control groups, involve different grade levels, and examine long-term effects of the model implementation to strengthen causal inference and generalizability.

REFERENCES

Abdullah, R. (2017). The effect of applying the jigsaw cooperative learning model to chemistry subjects at madrasah aliyah (in Bahasa). Lantanida Journal, 5(1), 13. https://doi.org/10.22373/lj.v5i1.2056

Ahmad, Ahmad, Usodo, Budi, & Riyadi, Riyadi. (2017). Eksperimentasi model pembelajaran kooperatif tipe group investigation (gi) dan jigsaw ii ditinjau dari kemampuan spasial siswa. *Jurnal Tatsqif*, *15*(1), 51–68. https://doi.org/10.20414/j-tatsqif.v15i1.1331

Arrahmah, Jestiwi, Kusuma, Yanti Yandri, & Fadhilaturrahmi, Fadhilaturrahmi. (2024). Peningkatan kemandirian belajar siswa dengan menggunakan model pembelajaran discovery learning di sekolah dasar. *Journal of Education Research*, *5*(2), 1105–1117. https://doi.org/10.37985/jer.v5i2.919

Fajri, Fenty Rahmawati, & Amir, Mohammad Faizal. (2022). Math self-regulated learning assisted by metacognitive support by reviewing sex differences in mathematics anxiety. *REID (Research and Evaluation in Education)*, *8*(2), 100–113. https://doi.org/10.21831/reid.v8i2.49157

Guntur, M., Muchyidin, A., & Winarso, W. (2017). Pengaruh penggunaan bahan ajar matematika bersuplemen komik terhadap kemandirian belajar siswa. *Eduma : Mathematics Education Learning and Teaching*, *6*(1), 43. https://doi.org/10.24235/eduma.v6i1.1667

Hafidzah, Nur Alfiani, Azis, Zainal, & Irvan, Irvan. (2021). The effect of open ended approach on problem solving ability and learning independence in students' mathematics lessons. *IJEMS:Indonesian Journal of Education and Mathematical Science*, *2*(1), 44. https://doi.org/10.30596/ijems.v2i1.6176

Hamsina, S., Bahri, A., Negeri, S., Negeri, S., Barru, Mt., & Studi Magister Pendidikan Biologi, P. (2023). Meningkatkan kemandirian belajar siswa melalui model pembelajaran opside increasing students' learning independence through opside learning model.

Prosiding Seminar Nasional Biologi FMIPA UNM, 437–444. https://journal.unm.ac.id/index.php/semnasbio/article/view/976

Husni Sabil, Sela Michella O. U. Simanjuntak, Dewi Iriani, & Ranisa Junita. (2024). Analysis of students' spatial ability in geometry material. *JPI (Jurnal Pendidikan Indonesia)*, *13*(3), 436–448. https://doi.org/10.23887/jpiundiksha.v13i3.77083

Indah, R. P., & Farida, A. (2021). Pengaruh kemandirian belajar siswa terhadap hasil belajar matematika. *Jurnal Derivat: Jurnal Matematika Dan Pendidikan Matematika*, *8*(1), 41–47. https://doi.org/10.31316/j.derivat.v8i1.1641

Iskandar, & Badruzzaman, Deden. (2017). Pengaruh think pair share, mind mapping dan jigsaw terhadap pemahaman konsep siswa. *Pengaruh think pair share, mind mapping dan jigsaw terhadap pemahaman konsep siswa*, *5*(3), 1657–1671.

Khoerunnisa, Putri, & Aqwal, S. M. (2020). Analisis model-model pembelajaran. Fondatia, 4(1), 1-27. *Jurnal Pendidikan Dasar*, *4*(1), 1–27.

Khulqi, Rifa'ul, Hanifah, Nurdinah, & Sunaengsih, Cucun. (2024). Pengaruh model pembelajaran kooperatif tipe jigsaw untuk meningkatkan berpikir tingkat tinggi siswa di kelas v. *Ideguru: Jurnal Karya Ilmiah Guru*, *9*(2), 1067–1074. https://doi.org/10.51169/ideguru.v9i2.967

Kurniasih, Ranti. (2017). Penerapan strategi pembelajaran fase belajar model van hiele pada materi bangun ruang sisi datar. *JURNAL SILOGISME: Kajian Ilmu Matematika Dan Pembelajarannya*, *2*(2), 61. https://doi.org/10.24269/js.v2i2.626

Kusmayadi. (2022). *Pengaruh model pembelajaran talking stick dipadu dengan metode pembelajaran snowball drilling sma negeri 1 kerambitan, kabupaten tabanan , indonesia pendahuluan menurut uu nomor 20 tahun 2003 , pendidikan adalah usaha sadar dan terencana untuk mewujudkan*. *2*(2), 86–105. https://e-journal.lp3kamandanu.com/index.php/biocaster/

Laili, N. (2021). Pengaruh self-efficacy dan motivasi belajar terhadap kemandirian belajar matematika. *Afeksi: Jurnal Penelitian Dan Evaluasi Pendidikan*, *2*(2), 98–103. https://doi.org/10.35672/afeksi.v2i2.35

Mardiana, I. N. (2022). Metode drill untuk meningkatkan hasil belajar penjasorkes pada siswa kelas vi sd. *Journal of Education Action Research*, *6*(2), 182–187. https://doi.org/10.23887/jear.v6i2.45821

Ma'Rifatin, S., Amin, S. M., & Siswono, T. Y. E. (2019). Students' mathematical ability and spatial reasoning in solving geometric problem. *Journal of Physics: Conference Series*, *1157*(4). https://doi.org/10.1088/1742-6596/1157/4/042062

Masruri. (2022). Model-model pembelajaran efektif dan inovatif dalam mata pelajaran sains (ipa) – (cooperative learning). *Cakrawala: Jurnal Pendidikan*, 316–322. https://doi.org/10.24905/cakrawala.vi0.227

Masyhudi, Rusyda. (2023). Penerapan model kooperatif learning tipe jigsaw dalam meningkatkan aktivitas belajar matematika siswa kelas ix 2022/2023 mtsn 1 kota padang. *Journal on Education*, *5*(4), 13586–13595. https://doi.org/10.31004/joe.v5i4.2367

Negara, H. R. P., Atmojo, T., & Sujadi, I. (2016). Eksperimentasi model pembelajaran kooperatif tipe jigsaw dengan pendekatan ctl terhadap prestasi belajar dan aspek afektif siswa pada materi bangun ruan. *Jurnal Tatsqif*, *3*(10), 1110–1126. Retrieved from https://jurnal.fkip.uns.ac.id/index.php/s2math/article/view/6684%0Ahttps://jurnal.fkip.uns.ac.id/index.php/s2math/article/download/6684/4549

Ningsih, EF, … M. Mardiyana Jurnal Pembelajaran, & 2014, undefined. (2014). Eksperimentasi model pembelajaran kooperatif tipe team assisted individualization (tai) dengan metode snowball drilling terhadap prestasi belajar matematika. *Jurnal.Uns.Ac.Id*, *2*(7). https://jurnal.uns.ac.id/jpm/article/view/10488

Ningsih, I. (2019). Kemampusan spasial matematis siswa smp kelas viii pada materi bangun ruang sisi datar. *Prosiding Seminar Nasional Matematika Dan Pendidikan Matematika Sesiomadika*, 623–631. https://journal.unsika.ac.id/index.php/sesiomadika/article/download/2662/1904

Nurhayati, Hermin, & , Langlang Handayani, Nuni Widiarti. (2020). Jurnal basicedu. Jurnal Basicedu,. *Jurnal Basicedu*, *5*(5), 3(2), 524–532. https://journal.uii.ac.id/ajie/article/view/971

Pane, Ramayenni. (2023). Model-model pembelajaran pendidikan matematika pada kurikulum merdeka. *BERSATU: Jurnal Pendidikan Bhinneka Tunggal Ika*, *1*(6), 21–30. https://doi.org/10.51903/bersatu.v1i6.433

Pertiwi, Putri Aulia, & Amaliyah, Nurrohmatul. (2024). *Pengembangan model pembelajaran jigsaw dengan media gambar untuk meningkatkan keterampilan berbicara siswa*. *13*(3), 3087–3096.

Puspaningtyas, Nuha, Prasetyo, Krisdianto Hadi, & Farahsanti, Isna. (2021). Penerapan model pembelajaran kooperatif snowball throwing dengan discovery learning untuk meningkatkan keaktifan dan prestasi. *Absis: Mathematics Education Journal*, *2*(1), 11. https://doi.org/10.32585/absis.v2i1.705

Ranti, Mayang Gadih, Budiarti, Indah, & Trisna, Benny Nawa. (2017). Pengaruh kemandirian belajar (self regulated learning) terhadap hasil belajar mahasiswa pada mata kuliah struktur aljabar. *Math Didactic: Jurnal Pendidikan Matematika*, *3*(1), 75–83. https://doi.org/10.33654/math.v3i1.57

Rusmini, M., Suarni, N. K., & Dharsana, I. K. (2024). Efektivitas pendekatan konseling cognitive behavior dengan teknik self-management untuk meningkatkan kemandirian belajar peserta didik kelas x perhotelan di smk negeri 1 singaraja. *Jurnal EDUCATIO: Jurnal Pendidikan Indonesia*, *10*(1), 125–286. https://doi.org/10.29210/1202322877

Saniatullaila, Nisfa, Wahyu, Rizki, Putra, Yunian, Sugiharta, Iip, Anwar, Chairul, Leni, Nurhasanah, Islam, Universitas, Raden, Negeri, Lampung, Intan, & Lampung, Bandar. (2024). Model pembelajaran jigsaw sebagai strategi meningkatkan kemandirian belajar siswa. *2*(2), 33–36.

Shoffa, Shoffan, & Suprapti, Endang. (2017). Peningkatan hasil belajar mahasiswa pada mata kuliah metode numerik dengan model pembelajaran kooperatif jigsaw. *MUST: Journal* *of Mathematics Education, Science and Technology*, 2(2), 178–188. Retrieved from http://journal.um-surabaya.ac.id/index.php/matematika/article/view/736

Sukarmini, N. N., Suharsono, N., Sudarma, I. K. (2016). *e-Journal Program Pascasarjana Universitas Pendidikan Ganesha Program Studi Teknologi Pembelajaran (Volume 6 Tahun 2016)*. 6(2). https://doi.org/10.36989/didaktik.v9i04.1807

Sulistiarini, Tri, Marmoah, Sri, & Sriyanto, Muhammad Ismail. (2023). Faktor yang mempengaruhi kemandirian belajar dalam projek penguatan profil pelajar pancasila. *Didaktika Dwija Indria*, 11(2). https://doi.org/10.20961/ddi.v11i2.75561

Syafitri, E., Taga, G., Seto, & Baptis, S. (2021). *JUPIKA : jurnal pendidikan matematika universitas flores metode pembelajaran snowball drilling untuk*. 4, 42–51. https://doi.org/10.53623/apga.v3i2.401

Tusaadia, Amina, Abdillah, Abdillah, Mahsup, Mahsup, Mandailina, Vera, & Syaharuddin, Syaharuddin. (2022). Learning independence towards mathematics learning outcomes based on education level. *Indonesian Journal Of Educational Research and Review*, 5(3), 577–587. https://doi.org/10.23887/ijerr.v5i3.52312

Yulia, Putri, & Amanda Putri, Fenti. (2024). Analisis kemampuan spasial matematis siswa dalam menyelesaikan masalah geometri bangun ruang. *MEGA: Jurnal Pendidikan Matematika*, 5(1), 697–705. https://doi.org/10.59098/mega.v5i1.1472

Windi, A., Kasmawati, A., & Suharman, A. (2024). Efektivitas penggunaan media powtoon terhadap hasil belajar siswa pada mata pelajaran bahasa indonesia kelas x di man 4 bone. BEGIBUNG: Jurnal Penelitian Multidisiplin. *BEGIBUNG: Jurnal Penelitian Multidisiplin*, 2(2), 330–336. https://doi.org/10.62667/begibung.v2i1

Wulansari, A. N., & Adirakasiwi, A. G. (2019). Analisis kemampuan spasial matematis siswa dalam menyelesaikan masalah matematika. *Prosiding Seminar Nasional Matematika Dan Pendidikan Matematika Seismodika*, 504–513. https://jurnal.mipatek.upgripnk.ac.id/index.php/JPPM/article/view/585