Kasetsart Journal of Social Sciences 43 (2022) 891–902

Kasetsart Journal of Social Sciences

journal homepage: http://kjss.kasetsart.org

An investigation of students' mathematical concept understanding and motivation through the implementation of aptitude treatment interaction learning model

Agustan Syamsuddin[a,*], Rosleny Babo[a,†], Sulfasyah[a], Hariati Bakri[a], Jainuddin[b]

[a] *Magister of Elementary Education, Postgraduate Program, Universitas Muhammadiyah Makassar, Makassar, South Sulawesi 90221, Indonesia*
[b] *Mathematics Education Department, Faculty of Teacher Training and Education, Universitas Bosowa, Makassar, South Sulawesi 90321, Indonesia*

Article Info

Article history:
Received 30 September 2021
Revised 20 March 2022
Accepted 23 March 2022
Available online 12 October 2022

Keywords:
ATI learning model,
learning motivation,
mathematical concept understanding

Abstract

This paper presents a result of investigation of elementary school 5th grade students' mathematical concepts understanding and learning motivation by implementing Aptitude Treatment Interaction (ATI) learning model. Therefore, the researchers selected quasi experiment with two group randomized subject post-test only design, involving 60 students as samples using random sampling technique. Data were taken using test of mathematical concept understanding and questionnaire of motivation and analyzed using descriptive and inferential statistical through t-test and manova to measure the influence of ATI learning model on students' mathematical concept understanding and motivations simultaneously. Descriptively, the average score of mathematical concepts understanding in ATI learning model is 81.90 with excellent category while the average score of mathematical concepts understanding in direct instruction model is 75.23 with good category. The average score of learning motivation with the ATI learning model is 130.03 with an excellent category while the direct instruction model is 109.93 with a good category. The result of the independent sample t-test and manova test shows that the implementation of ATI learning model meaningfully influenced students' mathematical concept understanding and motivation in learning mathematics.

Introduction

At the primary education level, the general purpose of mathematics subjects is preparing students to face the changes in life that are always evolving through action on the basis of logical, rational, critical, careful, efficient, effective and honest thinking (Haking et al., 2020). In addition, it was mentioned in the 2013 curriculum that the expected competencies related to mathematics learning are to develop creativity, curiosity, the ability to formulate questions to form critical thoughts that are needed to live intelligently and learn throughout life (Kemendikbud, 2013).

* Corresponding author.
E-mail address: agustan@unismuh.ac.id (A. Syamsuddin).
† Co-first authors.
E-mail address: rosleny@unismuh.ac.id (R. Babo).

https://doi.org/10.34044/j.kjss.2022.43.4.12
2452–3151/© 2022 Kasetsart University.

However, this expectation is far from the reality related to students' mathematical ability in Indonesia, where data obtained from the Program for International Students Assessment (PISA) in 2018 released on December 3, 2019, described that Indonesian students' mathematical ability was ranked 66th out of 73 countries. Indonesian students gained an average score of 379 with the Organization for Economic Co-operation and Development (OECD) average score of 487 while China, which was the 1st ranked, had an average score of 591 (Organization for Economic Co-operation and Development [OECD], 2019). Other data related to PISA 2018, found that teachers in Indonesia have a high enthusiasm in teaching their students, where the enthusiasm sequence of Indonesian teachers is in 4th position after Albani, Kosovo, and Korea. This indicates that teachers in Indonesia have seriousness in guiding students, but most of them do not understand the needs of each student. Thus, a teacher must pay attention to the characteristic aspects of each student that are unique so that the teacher can accommodate the differences that exist during the learning process (Syamsuddin, 2019).

One of the characteristics that teachers need to consider is the students' potential and intelligence (Hwang et al., 2020). In mathematics learning, the students' mathematical ability that needs to be developed is concept understanding (Anderson, 2009). It is stated in the National Education Standards Board Indonesia that one of the basic abilities that must be achieved by students is mathematical concepts understanding (Badan Standar Nasional Pendidikan [BSNP], 2006a). However, students often have difficulty in solving complex problems because they cannot integrate mathematical concepts (Syamsuddin et al., 2021a; Syamsuddin et al., 2021b). This is due to the students' tendency to only use counting and algorithm concepts (Al-Mutawah et al., 2019; Österman & Bråting, 2019).

Each student has different abilities in understanding a concept (Kenedi et al., 2019; Saygılı, 2017). Therefore, the teacher must pay attention to the students' ability to understand the concept so that the students will be motivated to participate in the learning process because they feel cared for and involved. (Bal-Taştan et al., 2018; Abramovich et al., 2019).

Teachers must always present comfortable situations during the learning process (Jacobi, 2018; Senthamarai, 2018). If students have high learning motivation, they will be ready to master subject matter (Abramovich et al., 2019). To accommodate the differences in students' ability and motivation, a learning model is needed that can help students to understand mathematical concepts based on the students' aptitude level. A learning model that can accommodate student's ability difference is the Aptitude Treatment Interaction (ATI) learning model.

The ATI learning model contains a number of learning strategies by developing effective learning conditions with different students' ability level (Lehmann et al., 2016). It is believed to provide opportunities for students to engage in discussions, think critically, and be brave and willing to take responsibility (Xu & Zhang, 2021). In addition, this model is believed to be able to support the implementation of the existing curriculum in Indonesia, namely the KTSP and K-13 curriculum (Babo et al., 2020).

The ATI learning model illustrates the existence of an interaction between the students' learning outcomes and the setting of learning conditions (Kärner et al., 2017). This means that the students' academic achievement is influenced by the learning conditions developed by the teacher in the classroom. Thus, the more suitable the treatment or learning method applied by the teacher by taking into account the aspects of students' different aptitude, the better it can motivate students to be involved in learning, which has an impact on the more optimal learning outcomes achieved. If the learning outcomes are more optimal, the students' understanding of mathematical concepts will increase.

Literature Review

One of the learning models that can be applied by teachers is the Aptitude-Treatment Interaction (ATI) learning model. It has a number of effective learning strategies used for individuals according to their respective abilities (Snow, 1989). It seeks to find strategies or treatments that match the differences in students' understanding (Cronbach & Snow, 1977). Therefore, paying attention to the student's talent aspects will lead to an optimization of students' learning outcomes (Gardner, 2011).

By applying the ATI learning model, it is expected that students' mathematical concept understanding can be achieved. It is one of the basic skills developed in mathematics subjects (BSNP, 2006b). However, this statement is not directly proportional to the condition that occurs in 5th grade students in Region I of Pangkajene Pangkep district, where the students can only solve the routine problems. In addition, the teachers tend to give equal treatment to all students (Syamsuddin et al., 2019).

This learning situation can cause a decrease in students' motivation because the teacher continues the material without paying attention to students' mathematical concepts understanding for groups with moderate and low abilities. Conversely, if the teacher does not proceed to the next material, then the high ability students will feel bored. For that reason, these two conditions greatly affect the student's learning motivation. While learning motivation is very influential on the success of learners in a subject (Arquero et al., 2015; Busato et al., 2000; Xiao, 2012).

Students have their own characteristics of learning a mathematical concept (Syamsuddin et al., 2020). Syamsuddin (2020) stated that students with a high-mathematical skill easily solve the math problems whereas students with moderate mathematical skill are more likely to take longer to solve mathematics because they need more time to identify and understand a mathematical concept. This potential can only be developed effectively through an integrated learning strategy (Bakri et al., 2020).

Enhancing students' mathematical concepts understanding by involving students' logical thinking skills is done by choosing an effective learning model (Bahtiar et al., 2020). By paying attention to students' diverse characteristics in processing information, a mentoring is needed that accommodates differences in students' ways (Agustan et al., 2017; Aisyah et al., 2020). A learning model that can be applied is the Aptitude Treatment Interaction (ATI) learning model, which emphasizes adjusting treatment to differences in student aptitude (Preacher & Sterba, 2019; Richard, 2018). It provides opportunities for students to engage in discussions, think critically and dare to take responsibility (Fyfe et al., 2012; Snow, 1991). In addition, this model gives students more time to think, analyze, answer and help each other to solve mathematical problems (Hanum et al., 2021). Therefore, students can be motivated in learning because they are given the opportunity to discuss with their friends (Bledow et al., 2017) and elaborate mathematical concepts needed, which has an impact on increasing students' mathematical concepts understanding (Apriyanto et al., 2019).

In this study, the ATI learning model consisted of four stages, namely, (1) Initial treatment is used to determine the classification of student groups based on their ability level; (2) Grouping students is based on the initial treatment. Students in the class are classified into three groups consisting of high, medium, and low ability; (3) Provide treatment. In this activity, each group is given treatment considered according to the students' characteristics and aptitude. All students are involved in the learning process so that they are motivated to understand the teaching material according to their respective abilities with teacher assistance. In this approach, high ability students are given treatment in self-learning through modules. Medium ability students are given regular teaching. Meanwhile, low ability students are given treatment in regular teaching and tutorials. Tutorials can be given by the mathematics teacher or by mentors who have received guidance from the teacher; and (4) Achievement-Test. In this activity, an assessment of students' mathematical concept understanding is carried out after each student abilities group has been given learning.

Hence, the involvement of students in mathematics learning in accordance with their respective abilities can motivate students to be more active in learning so that the ability to understand the mathematical concepts of students is also formed. By creating a learning setting which is adjusted to students' ability, such shows that there is an interaction between those aspects. It indicates that academic achievement and mathematics learning outcomes in this case is mathematical concept understanding, influenced by learning environment developed by the teacher in the classroom.

Methodology

This study used quasi experiment with a design of two group randomized subject post-test only (Fraenkel et al., 2012). This study had a control and an experimental class. The experimental class used the Aptitude Treatment Interaction (ATI) learning model, while the control class used a direct instruction model. After being given treatment, they were then given a students' mathematical concepts understanding test and learning motivation questionnaire. For more details, the research design is stated in Table 1 below.

Table 1 Research design

Class	Treatment	Post-test
Experimental Class	O_1	Y
Control Class	O_2	Y

Note: Y: Mathematical concept understanding test and learning motivation questionnaire, O_1: Treatment with the Aptitude Treatment Interaction (ATI) learning model, O_2: Treatment with the direct instruction model.

Participants and Data Collection

The population involved 280 students in 5th grade of elementary schools in region I Pangkajene Pangkep district consisting of 10 elementary schools. The number of samples taken were 60 students using random sampling techniques.

The research instruments were: (1) questionnaires of learning mathematics motivation. This questionnaire is in the form of open-ended questions so that students can provide answers as they wish regarding the description of their learning motivation after the application of the ATI learning model. The learning motivation scale was designed based on the Likert scale model (Likert, 1932), which contained a number of statements stating the object to be revealed (Edmondson, 2005). There are four answer options: always = 4, often = 3, seldom = 2, and never = 1. This questionnaire consisted of 30 items. Students' motivation scores are grouped into five categories by adapting the categorization guidelines according to the Ministry of Education and Culture (2009). The category of students' learning motivation (1.1) excellent if the score is 130–150; (1.2) good if the score is 105–149; (1.3) fair if the score is 80–104; (1.4) poor if the score is 55–79; and (1.5) very poor if the score is 30–54; and (2) Mathematical concept understanding test is used to measure students' ability to master materials based on the learning objective. It consists of 5 questions related to the concept of fractions. The scoring technique is given with the provisions (2.1) students understand what is known and asked from the questions, score of 5; (2.2) students describe the solution with the correct procedure, score of 10; and (2.3) students write the final answer clearly and accurately, score of 5. Score total is maximum of 100.

The categorization of students' mathematical concept understanding abilities is divided into 5 groups adapted from the guidelines for student learning outcomes categories according to the Ministry of Education and Culture (2009). The total score of (1) 80–100 is excellent; (2) 68–79 is good; (3) 55–67 is fair; (4) 45–54 is poor and (5) less than 45 is very poor.

The selected participants were divided into the experimental class and the control class. The experimental class was treated with the application of the Aptitude Treatment Interaction (ATI) learning model while the control class was applied the direct instruction model. In applying the ATI learning model, such consisted of four stages, which are described as follows.

Stage 1 is the initial treatment, namely, giving initial treatment to students using aptitude testing This first treatment is intended to determine the classification of student groups based on the level of ability and potential ability of each student. Stage 2 is grouping students, namely, grouping students based on the results of aptitude-testing (initial ability test). Students in the class are classified into 3 groups consisting of students with high, medium, and low abilities.

Stage 3 is to provide treatment. At this stage, each group of students is given treatment that is deemed suitable according to the students' characteristics. High-ability students are given treatment in self-learning independently. Students with moderate and low abilities are given general learning, where the teacher explains the material. Then students with low abilities are given more treatment re-teaching and tutorials, that can be given by tutors who have received instructions and guidance from the teacher.

Stage 4 is the achievement-test which is the final stage of the ATI learning model, where students were given mathematical concept understanding test and a questionnaire on students' motivation. This is done to measure the level of mastery of students' concepts of mathematical material that has been studied. In addition, it is to get an overview of student responses related to the application of the ATI learning model, which is expected to motivate students to learn mathematics.

Data Analysis

The collected data were processed using descriptive and inferential statistical analysis. Descriptive statistics are used to describe students' mathematical concept understanding scores and level of motivation to learn mathematics while inferential statistics are used to determine the difference in the students' mathematical concept understanding ability and motivation between classes taught using the ATI learning model and the direct instruction model.

Before the test is carried out, research data shall be examined first using prerequisite testing analysis, namely normality and homogeneity test. Furthermore, testing is carried out using independent t-test sample analysis. It is used to determine the effect of applying the ATI learning model to the students' mathematical concepts understanding and motivation. In addition, manova test is used to measure the influence of the ATI learning model students' mathematical concept understanding and motivation in learning mathematics simultaneously.

Results and Discussion

In implementation of the ATI model, the learning process is carried out by grouping students into three ability groups according to the classification obtained from the value of learning outcomes in the previous material which is supported by information from teachers in the field of mathematics studies. The grouping of students is labeled with high, medium and low ability groups. The ratio of high-ability students is 25 percent, 50 percent moderate students and 25 percent low-ability students.

Based on the results of observations, students from the high ability group did not experience difficulties when working on the students' worksheet and the questions in the students' book, so independent learning by the high ability group ran smoothly. Some students from the medium and low-ability groups had difficulty in doing the worksheet, but with help and guidance, they could complete them well. Tutorial activities went well, and students from low ability groups were enthusiastic about participating in tutorial activities even though the implementation was after school. After the ATI learning model was implemented, students were given a test for mathematical concept understanding and learning motivation. Students' mathematical concept understanding and learning motivation in learning mathematics on fraction material are described as follows.

The data obtained were descriptively analyzed by describing the score of students' mathematical concept understanding test results described as follows in Table 2. If the data above were distributed into five categories based on the adaptation results of the student learning outcome category guidelines according to the Ministry of Education and Culture (2009), then the distribution of frequency and percentage score of students' mathematical concepts understanding are as shown in the following Table 3.

Based on Table 2 and Table 3, it can be explained that the average score of students' mathematical concept understanding with the ATI learning model is at an excellent level while in the direct instruction model, it is at a good level. Furthermore, the result description of questionnaire on students' motivation with the ATI learning model and direct instruction model is described in the following table.

Table 2 Description of students' mathematical concept understanding

Statistics	Students' Mathematical Concept Understanding	
	ATI Learning Model	Direct Instruction Model
Number of respondents	30	30.00
Average	81.90	75.23
Standard Deviation	8.10	6.12
Variance	65.61	37.49
Range	37.00	25.00
Minimum	63.00	58.00
Maximum	100.00	83.00
Total Score	2397.00	2257.00

Table 3 Distribution and level of students' mathematical concept understanding

Score Interval	Category	ATI Learning Model		Direct Instruction Model	
		Frequency	Percent	Frequency	Percent
80 – 100	Excellent	13	43.33	3	10.00
68 – 79	Good	15	50.00	22	73.33
55 – 67	Fair	2	6.67	5	16.67
45 – 54	Poor	0	0	0	0
< 45	Very Poor	0	0	0	0
Total		30	100.00	30	100.00

The score of students' motivation with the implementation of the ATI learning model and direct instruction model are also grouped into five categories by adapting the guidelines according to the Ministry of Education and Culture (2009), obtaining the distribution of frequency and percentage of learning motivation score as shown in Table 5.

Based on Table 4 and Table 5, it can be explained that the average score of students' motivation in learning mathematics with the ATI learning model is at the excellent level, while in the direct instruction model, it is at a good level. To support the previous statement that there is a difference in average understanding of mathematical concepts and students' motivation in learning mathematics using the ATI learning model and direct instruction model, inferential statistical analysis is carried out. Before conducting it, assumption test or prerequisite analysis were conducted to find out the feasibility of using t-test on the research results. The assumption tests are normality test and homogeneity test. The following test results are presented based on the calculation results obtained as seen in Table 6.

From the data, it can be explained that students' mathematical concepts understanding and learning motivation with the application of the ATI learning model obtained a significant value of .200. Meanwhile, data related to students' mathematical concepts understanding and motivation with the application of the direct instruction model obtained a significance value of .247. The two data are said to be normal if the significance value obtained is greater than the significance level = .05. The significance value (p-value) in both is greater than the value of the significance level. Thus, it can be concluded that both data are normal. Moreover, the results of calculations related to the homogeneity test results on the application of the ATI learning model and direct instruction are as shown in Table 7.

Table 4 Score description of students' motivation in learning mathematics

Statistics	Students' Motivation in Learning Mathematics	
	ATI Learning Model	Direct Instruction Model
Number of respondents	30	30
Average	130.03	109.93
Standard Deviation	4.32	4.21
Variance	18.72	17.72
Range	19.00	19.00
Minimum	121.00	105.00
Maximum	140.00	124.00
Total Score	3451.00	3298.00

Table 5 Distribution and percentage of motivation level in learning mathematics

Score Interval	Category	ATI Learning Model		Direct Instruction Model	
		Frequency	Percent	Frequency	Percent
130–150	Excellent	15	50	0	0
105–129	Good	15	50	30	100
80–104	Fair	0	0	0	0
55–79	Poor	0	0	0	0
30–54	Very Poor	0	0	0	0
Total		30	30	100	30

Table 6 Result of data normality test

Factor	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	*df*	*p*	Statistic	*df*	*p*
ATI Learning Model	.106	30	.200*	.979	30	.790
Direct Instruction Model	.160	30	.247	.885	30	.104

Table 7 Result of data homogeneity test

Statistics		Levene Statistic	*df1*	*df2*	*p*
ATI Learning Model Direct Instruction Model	Based on Mean	.069	1	58	.794
	Based on Median	.167	1	58	.684
	Based on Median and with adjusted df	.167	1	57.439	.684
	Based on trimmed mean	.102	1	58	.750

From the table, it can be stated that the data of students' mathematical concepts understanding and motivation with the implementation of the ATI learning model and the direct instruction model obtained a significance value (p value) of .794. The criteria for the data are homogeneous if the significance value is ≥ .05. Thus, it can be concluded that the data of students' mathematical concepts understanding and mathematics learning motivation are in the homogeneous category.

Description of Students' Mathematical Concept Understanding with ATI Learning and Direct Instruction Model

The results of data analysis using independent sample *t*-test for data of 5th grade students' mathematical concept understanding obtained are shown in Table 8.

From the table, it can be seen that the t-count value for the data on students' mathematical concept understanding scores, both in the ATI learning model and the direct instruction model, is 2.517. Meanwhile, the t-table value is 1.697 with a significance value of .005, which is smaller than the value of = .05. Thus, *t*-count > *t*-table (2.517 > 1.697), so it can be argued that there are differences in students' mathematical concept understanding taught the ATI learning model and direct instruction model. The average score of students' mathematical concept understanding is at excellent level with the implementation of the ATI learning model while the average score of students' mathematical concept understanding is only at good level with the implementation of direct instruction model.

Description of Student Learning Motivation with ATI Learning and Direct Instruction Model

The results of data analysis using independent sample t-test for data of 5th grade students' motivation with the ATI learning model and direct instruction model obtained are shown in Table 9.

From the table it appears that the t-count value for the data on students' learning motivation taught by the ATI learning model and direct instruction model is 4.634, and the *t*-table value is 1.697 with a significance value of .0000, which is smaller than the value of = .05. Thus, t count > *t*-table (4.634 > 1.697), so it can be stated that there are differences in students' mathematics learning motivation, where the ATI learning model is effective to motivate students to be active in mathematics learning compared to the direct instruction model. The average score of students' motivations is at excellent level with the ATI learning model while the direct instruction model is only at the good level.

Furthermore, multivariate variant analysis (manova) test was conducted to test whether there are differences in students' mathematical concepts understanding and mathematical learning motivation with the ATI learning model and direct instruction model. The test results of multivariate variant analysis are described in Table 10.

Table 8 The result of *t*-test in data pairs of students' mathematical concept understanding

Statistical Value		*t*-value	*df*	*p*
Mathematical concept understanding	Equal variances assumed	2.517	58	.005
	Equal variances not assumed	2.517	53.9	.005

Table 9 The result of *t*-test in data pairs of students' motivations

Statistical Value		*t*-value	*df*	*p*
Motivation in learning mathematics	Equal variances assumed	4.634	58	.000
	Equal variances not assumed	4.634	57.96	.000

Table 10 Multivariate test result

	Effect	Value	*F*	Hypothesis *df*	Error *df*	*p*	Noncent. Parameter	Observed Power[d]
Intercept	Pillai's Trace	0.999	9187.372[b]	2.000	26.000	.000	18374.743	1.000
	Wilks' Lambda	0.001	9187.372[b]	2.000	26.000	.000	18374.743	1.000
	Hotelling's Trace	706.721	9187.372[b]	2.000	26.000	.000	18374.743	1.000
	Roy's Largest Root	706.721	9187.372[b]	2.000	26.000	.000	18374.743	1.000
ATI Learning Model	Pillai's Trace	0.629	6.194	4.000	54.000	.000	24.776	0.981
	Wilks' Lambda	0.407	7.384[b]	4.000	52.000	.000	29.537	0.994
	Hotelling's Trace	1.371	8.567	4.000	50.000	.000	34.270	0.998
	Roy's Largest Root	1.303	17.595[c]	2.000	27.000	.000	35.190	0.999

The table expresses that the *F* value in the data on students' mathematical concept understanding and learning motivation with the ATI learning model has a significance less than 0.05. That means the *F*-value for Pilae Trace, Wilk Lambda Hoteling Trace, Roy's Largest Root are all significant. This explains that there is a significant influence of the ATI learning model and direct instruction model on students' mathematical concept understanding and their motivation to learn mathematics. Subsequently, it was investigated whether there was a significant influence of the ATI learning model applied in the classroom on students' mathematical concept understanding and motivation simultaneously by looking at the results of MANOVA test described in Table 11.

The data of students' mathematical concept understanding and motivation with the ATI learning model show that there is an influence of implementing the ATI learning model to each student's mathematical concepts understanding and learning motivation, where obtained p-level value < from ά = .05 (Sig: .000 < .05) for both variables. The results also show that the students' mathematical concepts understanding with the ATI learning model is at an excellent level. This is made possible by the existence of a meaningful learning process for students, where students learn according to their level of ability (Fuchs et al., 2014) so that the process of understanding and reviewing problems takes place in a balanced manner, and it is easier for the students to understand the materials provided (Lehmann et al., 2016). Giving students the opportunity to develop themselves according to their abilities means giving students the opportunity to be able to interpret, analyze or manipulate information obtained during the learning process (Yee et al., 2015).

Table 11 Manova test result

Tests of Between-Subjects Effects								
Source	Dependent Variable	Type III Sum of Squares	*df*	Mean Square	*F*	*p*	Noncent. Parameter	Observed Power[c]
Corrected Model	Learning motivation	75.252[a]	2	37.626	2.172	.000	4.344	.405
	Mathematical concept understanding	730.319[b]	2	365.160	11.567	.000	23.134	.988
Intercept	Learning motivation	175968.47	1	175968.473	10158.229	.000	10158.229	1.000
	Mathematical concept understanding	85686.910	1	85686.910	2714.217	.000	2714.217	1.000
ATI Learning	Learning motivation	75.252	2	37.626	2.172	.000	4.344	.405
	Mathematical concept understanding	730.319	2	365.160	11.567	.000	23.134	.988
Error	Learning motivation	467.714	27	17.323				
	Mathematical concept understanding	852.381	27	31.570				
Total	Learning motivation	397523.00	30					
	Mathematical concept understanding	202811.00	30					
Corrected Total	Learning motivation	542.967	29					
	Mathematical concept understanding	1582.700	29					

ATI learning model provides various kinds of treatment, high-ability group students can freely study independently through modules and continue from one material to the next material without having to wait for other students. Meanwhile, students in the medium-ability and low-ability groups were given the opportunity to receive the lessons delivered by the teacher and had the opportunity to discuss and work together with their friends. In addition, the low-ability group was given additional learning by holding reteaching so that they can more freely ask questions and repeat material that was still not understood. Thus, these activities provide opportunities for students to engage in discussions, think critically, be brave and be willing to take responsibility for their own learning according to their abilities (Chen, 2019; Xu & Zhang, 2021). Learning mathematics using the ATI learning model emphasizes more on grouping students according to student abilities, encouraging student activity, motivating students to express ideas, encouraging students to think, observe, understand, try, guess, find, and review again (Hardy et al., 2019; Septiana et al., 2021).

The results of this study are in line with Maskur et al. (2020) that the learning model of Aptitude Treatment Interaction (ATI) can improve students' thinking skills in solving mathematics problems. However, a supportive learning environment is needed by improving students' mathematical understanding skills with contextual-based problems related to students' daily lives (Laurens et al., 2017; Sitorus & Masrayati, 2016; Suastika, 2017). Thus, the accuracy of a teacher in applying a learning model can improve students' mathematical concept understanding.

Similarly, the students' motivation with the Aptitude Treatment Interaction (ATI) learning model is much better in terms of categories in comparison with the direct instruction model. This is influenced by changes in the learning model that allow students to understand the material more easily, because they learn together with students who have the same level of ability so that each student feels no competition in material mastery (Seufert et al., 2009). This motivates students to learn because of the similarities (Gao, 2020). This suggests that mathematics learning should be designed to help students with low basic mathematics skills by considering the students' differences in terms of varied cognitive resources so that the students' motivation of learning mathematics is maintained (Krajewski & Schneider, 2009). Learning motivation is one of the aspects that must be considered in the process of learning mathematics (Montague, 2007; Rahman et al., 2020).

Conclusion and Recommendation

The results of this study give us an insight that each student has different characteristics and abilities, therefore the treatment must be in accordance with the students' character. By applying the ATI learning model, it can instill good students' mathematical concept understanding and increase students' motivation. This can be seen in the mean score of students' mathematical concept understanding with the ATI model of 81.90, which is at a very good level. Meanwhile, the average score of students' mathematical concept understanding with the direct instruction model is 75.23, which is at a good level. If viewed from the student's motivation, the average score of students' motivation with the ATI model is 130.03, which is at a very good level. Meanwhile, the average score of students' motivation with the direct instruction model is 109.93, which is at a good level. In addition, the result of inferential statistical test using the manova test indicates that the implementation of the ATI model significantly affects the students' mathematical concept understanding and mathematical learning motivation. Therefore, the Aptitude Treatment Interaction (ATI) model can be applied to motivate students to be active in the mathematics learning process, which has an impact on students' mathematics concept understanding well.

Conflict of Interest

The authors declare that there is no conflict of interest.

Acknowledgments

We would like to express our deepest appreciation to all those who provided us the possibility to complete this report. Special gratitude is given to Kemenristek dan Teknologi/Badan Riset dan Inovasi Nasional and LLDIKTI Wilayah IX who funded this research in the scheme "Penelitian Tesis Magister" based on decree number 8/E1/KPT/2020 January 24, 2020 and B/87/E3/RA.00/2020 January 28, 2020.

References

Abramovich, S., Grinshpan, A. Z., & Milligan, D. L. (2019). Teaching mathematics through concept motivation and action learning. *Education Research International*, *2019*, 1–13. https://doi.org/10.1155/2019/3745406

Agustan, S., Juniati, D., & Siswono, T. Y. E. (2017, August 23). *Profile of male-field dependent (FD) prospective teacher's reflective thinking in solving contextual mathematical problem* [Conference presentation]. International Conference on Mathematics: Pure, Applied and Computation (ICoMPAC). Surabaya, Indonesia. https://aip.scitation.org/doi/pdf/10.1063/1.4994437

Aisyah, N., S., Akib, I., & Syamsuddin, A. (2020). Identifying the influence of anxiety and self-reliance in learning towards mathematics learning performance of elementary school's students grade v. *International Journal of Scientific & Technology Research*, *8*(12), 3436-–3440, *9*(2), 3238–3242. https://www.ijstr.org/paper-references.php?ref=IJSTR-0120-30128

Al-Mutawah, M. A., Thomas, R., Eid, A., Mahmoud, E. Y., & Fateel, M. J. (2019). Conceptual understanding, procedural knowledge and problem-solving skills in mathematics: High school graduates work analysis and standpoints. *International journal of education and practice*, *7*(3), 258–273. https://doi.org/10.18488/journal.61.2019.73.258.273

Anderson, J. (2009, October 2–4). *Mathematics curriculum development and the role of problem solving* [Conference session]. ACSA National Biennial Conference Curriculum: A National Conservation. Canberra, Australia. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.493.6882&rep=rep1&type=pdf

Apriyanto, B., Ikhsan, F. A., Nurdin, E. A., Kurnianto, F. A., Puji, R. P. N., & Zulianto, M. (2019, March). *The influence of interaction aptitude-treatment (ATI) learning models in improving the geography learning achievement of class xi students in senior high school pgri lumajang* [Conference session]. International Conference on Environmental Geography and Geography Education (ICEGE), East Java, Indonesia. https://iopscience.iop.org/article/10.1088/1755-1315/243/1/012083

Arquero, J., L., Fernandez-Polvillo, C., Hassall, T., & Joyce, J. (2015). Vocation, motivation and approaches to learning: A comparative study. *Education + and Training*, *57*(1), 13-–30. https://doi.org/10.1108/ET-02-2013-0014

Babo, R., Ahmad, A. & Syamsuddin, A. (2020). Profile of primary school teachers view on curriculum changes: Case studies on implementing K-13 curriculum in primary schools in Makassar, Indonesia. *International Journal of Advanced Science and Technology*, *29*(04), 10260–10271. http://sersc.org/journals/index.php/IJAST/article/view/33064

Badan Standar Nasional Pendidikan. (*2006a*). *Guidelines for preparation of education unit level curriculum for elementary and secondary education*. Depdiknas RI.

Badan Standar Nasional Pendidikan. (*2006b)*. *Permendiknas RI No. 22 Tahun 2006 about content standards for elementary and secondary education units*. Depdiknas RI.

Bahtiar, A., Syamsuddin, A., & Akib, I. (2020). Description of mathematical communication skills, logical thinking and its influence on the ability of mathematical literacy for students of grade v elementary school. *International Journal of Scientific & Technology Research*, *9*(4), 1075–1078. https://www.ijstr.org/paper-references.php?ref=IJSTR-0420-34722

Bakri, H., Syamsuddin, A., & Babo, R. (2020). Applying the aptitude treatment interaction (ATI) learning model in mathematics learning to improve mathematical concept understanding of 5th grade of elementary school students. *Journal of Critical Reviews*, *7*(7), 55–58. http://dx.doi.org/10.31838/jcr.07.07.10

Bal-Taştan, S., Davoudi, S. M. M., Masalimova, A. R., Bersanov, A. S., Kurbanov, R. A., Boiarchuk, A. V., & Pavlushin, A. A. (2018). The impacts of teacher's efficacy and motivation on student's academic achievement in science education among secondary and high school students. *EURASIA Journal of Mathematics, Science and Technology Education*, *14*(6), 2353–2366. https://doi.org/10.29333/ejmste/89579

Bledow, R., Carette, B., Kühnel, J., & Bister, D. (2017). Learning from others' failures: The effectiveness of failure stories for managerial learning. *Academy of Management Learning & Education*, *16*(1), 39–53. http://doi.org/10.5465/amle.2014.0169

Busato, V. V., Prins, F. J., Elshout, J. J., & Hamaker, C. (2000). Intellectual ability, learning style, personality, achievement motivation and academic success of psychology students in higher education. *Personality and Individual Differences*, *29*(6), 1057–1068. https://doi.org/10.1016/S0191-8869(99)00253-6

Chen, J. (2019). Exploring the impact of teacher emotions on their approaches to teaching: A structural equation modelling approach. *British Journal of Educational Psychology*, *89*(1), 57–74. https://psycnet.apa.org/doi/10.1111/bjep.12220

Cronbach, L. J., & Snow, R. E. (1977). *Aptitudes and instructional methods: A handbook for research on interactions*. Irvington. https://psycnet.apa.org/record/1978-11462-000

Edmondson, D. R. (2005, April 28 – May 1). *Likert scales: A history* [Conference session]. In L. C. Neilson (Ed.), Proceedings of the 12th Conference on Historical Analysis and Research in Marketing (CHARM) (pp.127–133). California, USA University of South Florida. https://ojs.library.carleton.ca/index.php/pcharm/article/view/1613

Fraenkel, J. R., Wallen, N. E., & Hyun, H. H. (2012). *How to design and evaluate research in education* (8th ed.). McGraw-Hill.

Fuchs, L. S., Schumacher, R. F., Sterba, S. K., Long, J., Namkung, J., Malone, A., Hamlett, C. L., Jordan, N. C., Gersten, R., Siegler, R. S., & Changas, P. (2014). Does working memory moderate the effects of fraction intervention? An aptitude–treatment interaction. *Journal of Educational Psychology*, *106*(2), 499–514. https://psycnet.apa.org/doi/10.1037/a0034341

Fyfe, E. R., Rittle-Johnson, B., & DeCaro, M. (2012). The effects of feedback during exploratory mathematics problem solving: Prior knowledge matters. *Journal of Educational Psychology*, *104*(4), 1094–1108. https://psycnet.apa.org/doi/10.1037/a0028389

Gao, J. (2020). Sources of mathematics self-efficacy in Chinese students: A mixed-method study with Q-sorting procedure. *International Journal of Science and Mathematics Education*, *18*(4), 713–732. https://doi.org/10.1007/s10763-019-09984-1

Gardner, H. E. (2011). *Frames of mind: The theory of multiple intelligences*. Basic books.

Haking, H., Syamsuddin, A., & Idawati. (2020). Testing the validity of a problem solving-based students' worksheet on space material for 5th grade elementary school students. *Journal of critical reviews*, *7*(9), 1248–1250. https://library.unismuh.ac.id/uploaded_files/temporary/DigitalCollection/ODA2YmRlMzk5NzMyZWEwMzNkYWZmZGQ4YThkNDdhM2ZmNmFkNjRkYw==.pdf

Hanum, O., Johar, R., & Yusrizal. (2021, October 20–22). Students' thinking process in solving Higher-Order Thinking (HOT) problems through Aptitude Treatment Interaction (ATI) learning model [Conference session]. *Journal of Physics: Conference series* (Vol. 1882), South East Asia Science, Technology, Engineering and Mathematics International Conference (SEA-STEM IC), Aceh, Indonesia. https://iopscience.iop.org/article/10.1088/1742-6596/1882/1/012086/meta

Hardy, I., Decristan, J., & Klieme, E. (2019). Adaptive teaching in research on learning and instruction. *Journal for Educational Research Online*, *11*(2), 169–191. https://doi.org/10.25656/01:18004

Hwang, G. J., Xie, H., Wah, B. W., & Gašević, D. (2020). Vision, challenges, roles and research issues of artificial intelligence in education. *Computers and Education: Artificial Intelligence*, *1*(2020), 100001. https://doi.org/10.1016/j.caeai.2020.100001

Jacobi, L. (2018). What motivates students in the online communication classroom? An exploration of self-determination theory. *Journal of Educators Online*, *15*(2). https://doi.org/10.9743/jeo.2018.15.2.1

Kärner, T., Sembill, D., Aßmann, C., Friederichs, E., & Carstensen, C. H. (2017). Analysis of person-situation interactions in educational settings via cross-classified multilevel longitudinal modeling: Illustrated with the example of students' stress experience. *Frontline Learning Research*, *5*(1), 16–42. https://doi.org/10.14786/flr.v5i1.137

Kemendikbud (2013). *Permendikbud No. 54 concerning competency standard for graduates of primary and secondary education*. Kementerian Pendidikan dan Kebudayaan. http://repositori.kemdikbud.go.id/4265/1/01-a-salinan-permendikbud-no-54-tahun-2013-ttg-skl.pdf

Kenedi, A. K., Helsa, Y., Ariani, Y., Zainil, M., & Hendri, S. (2019). Mathematical connection of elementary school students to solve mathematical problems. *Journal on Mathematics Education*, *10*(1), 69–80. https://doi.org/10.22342/jme.10.1.5416.69-80

Krajewski, K., & Schneider, W. (2009). Early development of quantity to number-word linkage as a precursor of mathematical school achievement and mathematical difficulties: Findings from a four-year longitudinal study. *Learning and Instruction*, *19*(6), 513–526. https://doi.org/10.1016/j.learninstruc.2008.10.002

Laurens, T., Batlolona, F., Batlolona, J., & Leasa, M. (2017). How does Realistic Mathematics Eeducation (RMErme) improve students' mathematics cognitive achievement? *Eurasia Journal of Mathematics, Science and Technology Education*, *14*(2), 569–578. https://doi.org/10.12973/ejmste/76959

Lehmann, J., Goussios, C., & Seufert, T. (2016). Working memory capacity and disfluency effect: An aptitude-treatment- interaction study. *Metacognition Learning*, *11*(1), 89–105. https://doi.org/10.1007/s11409-015-9149-z

Likert, R. (1932). A technique for the measurement of attitudes. *Archives of Psychology*, *22(140),* 55. https://psycnet.apa.org/record/1933-01885-001

Maskur, R., Sumarno, S., Rahmawati, Y., Pradana, K., Syazali, M., Septian, A., & Kinarya Palupi, E. (2020). The effectiveness of problem based learning and aptitude treatment interaction in improving mathematical creative thinking skills on Curriculum 2013. *European Journal of Educational Research*, *9*(1), 375–383. https://doi.org/10.12973/eu-jer.9.1.375

Ministry of Education and Culture (2009) *Evaluation and assessment. Teacher quality improvement project*. Dirjen Dikdasmen.

Montague, M. (2007). Self-regulation and mathematics instruction. *Learning Disabilities Research & Practice*, *22*(1), 75–83. https://doi.org/10.1111/j.1540-5826.2007.00232.x

Organization for Economic Co-operation and Development. (2019), *PISA 2018 Results (Volume I): What students know and can do.* OECD Publishing. https://doi.org/10.1787/5f07c754-en

Österman, T., & Bråting, K. (2019). Dewey and mathematical practice: Revisiting the distinction between procedural and conceptual knowledge. *Journal of Curriculum Studies*, *51*(4), 457–470. https://doi.org/10.1080/00220272.2019.1594388

Preacher, K. J., & Sterba, S. K. (2019). Aptitude-by-treatment interactions in research on educational interventions. *Exceptional Children*, *85*(2), 248–264. https://doi.org/10.1177%2F0014402918802803

Rahman, S., Syamsuddin, A., & Babo, R. (2020). Implementation of thematic learning model to increase mathematics learning interest of elementary school' students. *Journal of Critical Reviews*, *7*(7), 534–537. http://dx.doi.org/10.31838/jcr.07.07.94

Richard, E. (2018). Aptitude-treatment interactions in educational research and evaluation. *Contemporary Issues in Educational Testing*, *9*, 229–247. https://doi.org/10.1515/9783111557045-017

Saygılı, S. (2017). Examining the problem-solving skills and the strategies used by high school students in solving non-routine problems. *E-International Journal of Educational Research*, *8*(2), 91–114. http://www.e-ijer.com/tr/download/article-file/338828

Senthamarai, S. (2018). Interactive teaching strategies. *Journal of Applied and Advanced Research*, *3*(1), S36–S38. https://doi.org/10.21839/jaar.2018.v3iS1.166

Septiana, E., Zubainur, C. M., & Ramli, M. (2021, October 20–22). *The enhancement of student's mathematical understanding ability through the Aptitude Treatment Interaction (ATI) learning model* [Conference session]. Journal of Physies: Conference Series South East Asia Science, Technology, Engineering and Mathematics International Conference (SEA-STEM IC), Aceh, Indonesia. https://iopscience.iop.org/article/10.1088/1742-6596/1882/1/012072

Seufert, T., Schütze, M., & Brünken, R. (2009). Memory characteristics and modality in multimedia learning: An aptitude–treatment–interaction study. *Learning and Iinstruction*, *19*(1), 28–42. https://doi.org/10.1016/j.learninstruc.2008.01.002

Sitorus, J., & Masrayati. (2016). Students' creative thinking process stages: Implementation of realistic mathematics education. *Thinking Skills and Creativity*, *22*(1), 111–120. https://doi.org/10.1016/j.tsc.2016.09.007. https://doi.org/10.1016/j.tsc.2016.09.007

Snow, R. E. (1989). Aptitude-treatment interaction as a framework for research on individual differences in learning. In P. L. Ackerman, R. J. Sternberg, & R. Glaser (Eds.), *Learning and individual differences: Advances in theory and research* (pp. 13–59). W H Freeman/Times Books/ Henry Holt & Co. https://psycnet.apa.org/record/1988-98749-002

Snow, R. E. (1991). Aptitude-treatment interaction as a framework for research on individual differences in psychotherapy. *Journal of Consulting and Clinical Psychology*, *59*(2), 205–216. https://psycnet.apa.org/doi/10.1037/0022-006X.59.2.205

Suastika, K. (2017). Mathematics learning model of open problem solving to develop students' creativity. *International Electronic Journal of Mathematics Education*, *12*(3), 569–577. https://doi.org/10.29333/iejme/633

Syamsuddin, A. (2019, September 19–20). The impact of implementing of INSTAD model toward student's mathematics learning outcome for 5th grade elementary school students [Conference session]. Seminar on Advances in Mathematics, Science and Engineering for Elementary School, Universitas Pendidikan Indonesia, Indonesia https://iopscience.iop.org/article/10.1088/1742-6596/1318/1/012021/meta.

Syamsuddin, A. (2020). Describing taxonomy of reflective thinking for field dependent-prospective mathematics teacher in solving mathematics problem. *International Journal of Scientific & Technology Research*, *9*(3), 4418–4421. http://www.ijstr.org/paper-references.php?ref=IJSTR-0320-32438.

Syamsuddin, A., Sukmawati, Mustafa, S., Rosidah, & Ma'rufi. (2021a). Analysing the skill of writing a scientific article as a written communication skill of prospective elementary school teacher on learning mathematics. *Journal of Educational and Social Research*, *11*(5), 88. https://doi.org/10.36941/jesr-2021-0108

Syamsuddin, A., Babo, R., Sulfasyah, & Rahman, S. (2021b). Mathematics learning interest of students based on the difference in the implementation of model of thematic learning and character-integrated thematic learning. *European Journal of Educational Research*, *10*(2), 581–591. https://doi.org/10.12973/eu-jer.10.2.581

Syamsuddin, A., Jannah, M., & Kristiawati, K. (2019). Implementation of the explicit instruction model in mathematical learning roman number for IV grade students of sd inpres kapasa makassar. *MaPan: Journal of Mathematics and Learning/MaPan: Jurnal Matematika dan Pembelajaran*, *7*(1), 136–154. https://doi.org/10.24252/mapan.2019v7n1a11.

Syamsuddin, A., Juniati, D., & Siswono, T. Y. E. (2020). Understanding the problem solving strategy based on cognitive style as a tool to investigate reflective thinking process of prospective teacher. *Universal Journal of Educational Research*, *8*(6), 2614–2620. https://doi.org/10.13189/ujer.2020.080644

Xiao, J. (2012). Tutors' influence on distance language students' learning motivation: Voices from learners and tutors. *Distance Education*, *33*(3), 365–380. https://doi.org/10.1080/01587919.2012.723167

Xu, T., & Zhang, B. (2021). Improving thinking skills in early childhood using effective teaching strategies. *Aggression and Violent Behavior*, 101704. https://doi.org/10.1016/j.avb.2021.101704

Yee, M. H., Yunos, J. M., Othman, W., Hassan, R., Tee, T. K., & Mohamad, M. M. (2015). Disparity of learning styles and higher order thinking skills among technical students. *Procedia-Social and Behavioral Sciences*, *204*, 143–152. https://doi.org/10.1016/j.sbspro.2015.08.127