EFFECT OF AN INSTRUCTIONAL DESIGN BASED ON THE ALGO-HEURISTIC THEORY OF INSTRUCTION ON STUDENTS' MATHEMATICS PERFORMANCE AND LOGICAL THINKING SKILLS

Abstract: The main aim of this research is to examine the effect of an instructional design based on the Algo-Heuristic Theory of Instruction (AHTI) on students' mathematics performance and logical thinking skills in the subject of 7th grade mathematics. The research is grounded in a mixed method. In the quantitative part of the research, a quasi-experimental design including pretest, posttest, retention test and retention monitoring test with experimental, placebo and control groups is used, while the qualitative section is based on a case study. The study group of the research consisted of three classes at a secondary school having a "medium" level of achievement. The quantitative and qualitative data of the study revealed that with the effect of the instructional design based on the AHTI, the mathematics performance of students in the experimental group increased, and that their logical thinking skills were positively impacted. Furthermore, it was revealed that students in the experimental group were able to transfer the stages of the Landamatics algorithm that they learned in the unit named "Ratios and Proportions" to their performance in science.

Keywords: Algo-Heuristic Theory of Instruction, Mathematics Instruction, Logical Thinking Skills, Science Performance.

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INTRODUCTION

Since mankind first appeared on the world stage, mathematics has had great importance in achieving the technology used in shaping the current world. For this reason, from past to present, importance has always been given to mathematics instruction. The value of mathematics in the modern world, in which developments in the field of science and technology play increasingly effective roles, is indisputable (Jacobs, et. al., 2007, p. 258).

On the other hand, the conducted studies (Baykul, 1991; Fidan and Baykul, 1991 and 1992; MEB, 1999 and 2003; cited in Baykul, 2014; MEB-PISA, 2016, MEB-TIMMS, 2016) reveal that student achievement in the subject of mathematics, which is so important, is generally low. The results obtained by the Turkish Ministry of National Education (MEB) in the central examination system, which has been frequently changed (LGS, OKS, SBS, TEOG and LGS) in recent years for entry into secondary education (high school), show similarity with the results of the current study. As a reflection of this situation, the subject of mathematics in schools is perceived as a difficulty which is faced by many students throughout their educational lives.

The contemporary understanding of education has subjected teachers to the necessity and responsibility of choosing and applying instructional approaches which will achieve learning at the highest level (Yılmaz, 2001; cited in Tatar and Dikici, 2008, p. 184). In mathematical education, conceptual and computational information complement each other and conceptual information is essential for application of computational information (Baki and Kartal, 2004; Soylu and Aydın, 2006; cited in Özbek and Uyumaz, 2020). Since the subject of mathematics has a symbolic and abstract nature (Steiner, 2007), it differs in a number of characteristics from other branches of science such as practical and social sciences (cited in İlhan, et. al., 2013, p. 117). Therefore, when the approaches to be used in mathematics instruction for increasing students' performance are being determined, it is important for the specific structure of the subject of mathematics to be taken into consideration. One of the approaches that can be used in mathematics teaching is the Algo-Heuristic Theory of Instruction (AHTI).

The AHTI was developed in the 1950s by Lev Landa. This theory is concerned with the cognitive processes that take place during the elementary and systematic analysis of information and the acquisition and implementation of information, as well as with the psychomotor skills. This theory allows students to internalise the thought processes and steps of understanding that they need to use when they are learning something new. By enabling learners to develop their general thought processes, it teaches them to understand information better, become high-level learners and transfer knowledge to new situations (Setiawan, 2007, p. 276).

The AHTI is also known as *Landamatics*. The theory, which was first referred to as the AHTI, was later expressed as Landamatics by American academicians (Landa, 1995, p. 1). The aim of Landamatics is, by means of thought methods based on small elements and clear information, to solve different problems having similar logical structures.

There are three methods for using instructional strategies included in the Landamatics approach (Reigeluth, 1999):

1. Guided Discovery: A method requiring the use of the six steps.
2. Expository Teaching: The same six steps are performed as in guided discovery, but the first two steps are given in ready form to students with suitable demonstrations.
3. Combination Approach: Depending on the teacher's objectives, some steps are taught with the discovery method and some with the expository method.

Setiawan (2007, p. 276) states that despite many benefits and areas of use, a number of problems can be experienced with implementation of Landamatics at primary school level. He states that for students to extract the desired information from educational materials, they will require the assistance of the teacher. He states the fact that students at that level do not possess summarisation and analysis skills as the reason for this. According to Setiawan, the AHTI can be applied to students at secondary level and above. The fact that at secondary level, students have entered the period of abstract operation, increases the possibilities for the AHTI to be implemented in the instruction of different subjects. One of these subjects is that of mathematics. Mathematics is one of the important tools used for solving problems, not only in science, but also in our daily lives. Due to this importance, outcomes related to mathematics are included in curricula at

all levels and in all fields from elementary education, and even preschool education programmes, right up to postgraduate education programmes. The reason why the necessary importance is given to mathematics teaching in schools at all levels and in all countries is that mathematics is an indispensable tool in scientific studies and in daily life (Baykul, 2014, p. 26).

As a result of the search for a system in education in Turkey, it is seen that in recent years, changes have been made to curricula at various intervals. From the 2005-2006 academic term onwards, radical changes encompassing all subjects have been made to primary curricula (Çırakoğlu and Saracaloğlu, 2009). In line with these changes, the secondary school mathematics curriculum was also revised in 2006 and 2009, and later in 2013, 2017 and 2018.

Scientific thinking skills such as: observation, classification, measurement, conclusion, forecasting, judging, induction, inference, data interpretation, variables control, etc. The application of these skills is one of the fundamental objectives of scientific education. When these skills are acquired by students, they help them to cope with renewable life problems (Adel, 2020, p. 69). Another of the competences that play an important role in student achievement in mathematics instruction is logical thinking skills. The skill of logical thinking, which is one of the cognitive skills, occupies an important place in students' success (Barr, 1994). Logical thinking ability is one of the most frequently emphasised subjects in studies conducted in the field of education. Studies related to logical thinking skills (Gökçe and Saraçoğlu, 2018; Ayal et al., 2016; Korkmaz, 2016; Bouhnik and Giat, 2009; Bozdoğan, 2007; Johnson and Lawson, 1998; Valanides, 1996) reveal that there is a positive relationship between logical thinking ability and achievement.

The aim of this study is to examine the effect of an instructional design developed based on the AHTI on seventh-grade students' mathematics performance and logical thinking skills in the subject of mathematics. As a result of the pilot study that was conducted, it was determined that learning environments based on the AHTI in the subject of mathematics were effective in ensuring students' retention of information for learning geometry and in fostering problem-solving and mathematical thinking skills in students. Based on this, enriching the literature with a similar study was considered necessary.

The main aim of the study is to examine the effect of an instructional design developed according to the AHTI on seventh-grade students' mathematics performance and logical thinking skills in the subject of mathematics. Within the scope of the main aim of the research, the hypotheses and subproblems for which answers were sought are given below:

1. There is a statistically significant difference between students in the experimental group of the mathematics instruction design based on the AHTI, and those in the control and placebo groups in terms of :
   a) Scores in the mathematics achievement pre-test, post-test, retention test and retention monitoring test,
   b) Scores for logical thinking skills, and
   c) Scores in the science achievement test.
2. What are the views of students regarding the mathematics instruction design based on the AHTI?
3. How do students behave in relation to the mathematics instruction design based on the AHTI, according to observers' perceptions?

METHOD

DESIGN

This research is based on a mixed design. Due to the nature of the research problem, qualitative and quantitative data were gathered together in the study. In this, design was used, in which the qualitative and quantitative data were gathered concurrently or consecutively, which could be used to answer the hypotheses and subquestions, and in which the analyses of the data sets were conducted independently of one another. In the quantitative part of the research, a quasi-experimental design including pre and post-tests, retention test, and retention monitoring test with experimental, placebo and control groups was used, while the qualitative section is based on a case study. The research design is a 3x4 mixed design.

In this research, with the aim of revealing the differences that might occur in the experimental group due to the instructional programme that was applied, besides the control group, a placebo group was included. The reason for selecting the placebo group in this study was to monitor any change brought about in

participants' behaviours by the presence of the researcher or by the awareness of the participant that he/she was being observed, and thereby, to increase the strength of the experimental design.

SAMPLE

The study group for the implementation of the research consisted of 88 students attending three different classes of the seventh grade at a public secondary school affiliated to the Ministry of National Education and located in the district of Çiğli, Izmir Province, in the 2017-2018 academic year, in Turkey. Using the multi-stage cluster sampling method, three 7th grade classes from the school where the implementation was to be made were each assigned to the experimental, placebo and control groups, respectively. Information related to the students who participated in the study is given in Table 1.

Table 1. Participant Information

Group	Gender		Total
	Female	Male	
Experimental	17	11	28
Control	16	14	30
Placebo	17	13	30
Total	50	38	88

DATA COLLECTION TOOLS

The data were gathered by means of a mathematics achievement test, a logical thinking skills test, a science achievement test (open-ended form), a semi-structured interview form, reflective diaries and an observation form.

MATHEMATICS ACHIEVEMENT TEST (MAT)

The MAT was developed and used by the researcher to determine the levels of achievement of students participating in the research in the subject of mathematics with regard to the unit named "Ratios and Proportions".

The item strength and item discrimination values of the items of the developed MAT were analysed according to the criterion value intervals table, and the items that needed to be removed and items that could be included in the test were determined.

According to the item analyses, the item strengths of the questions were revealed to be at easy or medium levels, and their item discrimination levels were determined as medium or good. Following the item analyses that were made, items that needed to be rejected and items with low discrimination values according to the criterion values were removed from the test, and the number of questions was reduced to 25. When the values related to the 25-question multiple choice MAT are examined, it is seen that the values calculated were 13.98 for arithmetic mean, 6.93 for standard deviation, 18.00 for mode, 17.00 for median, .56 for average strength and .92 for KR-20 value. By giving the multiple choice MAT its final form, this test was used to determine students' academic achievement related to the subject of mathematics. For the MAT, their normal distribution was examined within each group (experiment, control, and placebo). To examine whether there was a difference among the groups' mathematics achievement test scores before the implementation, the mean pre-test scores were compared. The equivalence of variance of pre-test scores before the analysis ($p=.082$) was checked, and the hypothesis that "there is no statistically significant difference in variance between groups" was accepted ($p>.05$).

LOGICAL THINKING SKILLS TEST (LTST)

The LTST was developed by Tobin and Capie (1981), and a reliability value of .79 was calculated for its original form. The Turkish translation and adaptation of the test was carried out by Geban, et. al. (1992), and a Cronbach alpha internal consistency reliability coefficient of .77 was found for the test. For the present study, an internal consistency reliability coefficient of .85 was calculated.

OPEN-ENDED SCIENCE ACHIEVEMENT TEST (SAT)

The SAT was developed with the aim of examining the possible effects of the AHTI on the achievement of outcomes of students in the experimental group on the topic of "Mirrors" in the unit named "Interaction of Light with Matter".

For the question items prepared according to the 2 outcomes related to the topic of "Mirrors" included in the "Interaction of Light with Matter" unit of the 7th grade science curriculum, the views of an expert in

the field of science (a faculty member), curriculum development specialists (three faculty members and two doctoral research assistants), three science teachers and one Turkish teacher were sought.
The SAT, which was developed with the aim of examining the possible effects of the AHTI on the achievement of outcomes of students in the experimental group in the topic of "Mirrors" in the unit named "Interaction of Light with Matter", was also applied to designated students to determine whether or not students in the experimental group used the stages of the Landamatics algorithm that they had learnt, in different disciplines. Accordingly, the test was applied to the specified students -a total of six students obtaining the highest scores (three students) and the lowest scores (three students)- based on the "extreme or deviant case sampling" method of purposive sampling. While the specified six students attempted to solve the test individually by reasoning out loud, they were video-recorded.
The SAT consisting of open-ended questions was developed with the aim of examining the possible effects of the AHTI on experimental group students' achievement of the outcomes in the "Mirrors" unit. The science achievement test was evaluated by three different raters (the subject teacher and two branch teachers) using a graded scoring key, by applying it to the experimental, control and placebo groups. When Kendall's coefficient of concordance was examined, a statistically significant degree of concordance was observed between the assessments made by the three raters ($W=.94$; $p<.01$).
Normal distribution within the experimental, control and placebo groups was examined for the science achievement test. When the statistics for the experimental, control and placebo groups in the SAT are examined according to the Shapiro-Wilk test, it is seen that normal distribution was achieved ($p>.05$).

SEMI-STRUCTURED INTERVIEW FORM

For the interviews conducted with the students who took part in the research, a semi-structured interview form, consisting of four open-ended questions prepared in line with the aims of the research, was developed. While the interview forms were being developed, subjects aimed at determining the perceptions and feelings of students in the experimental group regarding the implemented programme were taken into consideration. For the validity of the draft form, the views of a total of six experts, namely, two mathematics teachers, three faculty members working in the curriculum and instruction department and one Turkish teacher, were obtained, and the interview questions were revised based on the feedback provided by the experts. Following the expert views obtained for the interview questions included in the form, interviews were held with three students for the purpose of a pilot study, questions that were unclear or difficult to understand were revised, and the interview form was given its final shape.

OBSERVATION FORM

Within the scope of the research subject, in the experimental group, with the aim of revealing the observations related to student behaviours in the teaching-learning process with which the instruction based on the AHTI was implemented, field notes were taken by the researcher and branch teacher. For this purpose, an observation form, comprising six steps to conform with the steps of the AHTI, was developed. After the preparation of the draft observation form, for its validity, the views of three curriculum development specialists, all of whom are faculty members, were sought. In line with the views provided by these experts, the observation form was given its final shape.

REFLECTIVE DIARY

Within the scope of the research subject, in the experimental group, a reflective diary was created in order to determine the perceptions, views and feelings of students in the experimental group regarding the teaching-learning process with which the instruction based on the AHTI was implemented. On each page of the reflective diary are questions for students to answer, related to how the activities conducted in the lesson had gone, what the students had done and how they thought they performed during the activities. Following the preparation of the draft reflective diary, for its validity, three curriculum development specialists, all of whom are faculty members, were consulted for their views. In line with the views provided by these experts, the reflective diary was given its final shape.

DATA COLLECTION

The quantitative data of the research were collected with the measurement tools that would be used in the experimental model. The qualitative data of the research were gathered with a diversification strategy using three different qualitative data collection techniques. The researcher participated in the instruction process

in the experimental group as an observer, and carried out the structured observation process. Moreover, apart from the researcher, another mathematics teacher also took part in the instruction process as an observer by keeping field notes on the observation form. The reflective diaries (record books) kept by the students formed the data sources in the document examination section of the research. Following the implementation of the instruction programme, students in the experimental group were separated into lower, middle and upper groups according to their posttest scores. Then, information about students in each group was obtained from the classroom teacher. Next, interviews were held with specified students related to their voluntariness for participating in the study. Finally, nine students (three from each group) were specified, and interviews were conducted with these students.

DATA ANALYSIS AND INTERPRETATION

The analysis of the data collected via the tests and measurement tool was performed with the SPSS 21 software program. After entry of the data, independent samples t-test was used to measure differences within groups, while two-factor repeated measures ANOVA was used to measure differences between groups. In the scoring key that was prepared for the open-ended measurement tool for science achievement, concordance between the scores of three different scorers was examined using Kendall's coefficient of concordance. The SAT, which was developed with the aim of examining the possible effects of the AHTI on the achievement of outcomes of students in the experimental group in the topic of "Mirrors" in the unit named "Interaction of Light with Matter", was also applied to designated students to determine whether or not students in the experimental group used the stages of the Landamatics algorithm that they had learnt, in different disciplines. Accordingly, the test was applied to the specified students -a total of six students obtaining the highest scores (three students) and the lowest scores (three students)- based on the "extreme or deviant case sampling" method of purposive sampling. While the specified six students attempted to solve the test individually by reasoning out loud, they were video-recorded. The video recordings lasted 7 minutes on average. By watching the video recordings together with a mathematics field expert who is a faculty member, the question of whether the students had used their reasoning skills according to the steps of the Landamatics algorithm in their problem-solving process was analysed with the typological analysis technic.

For analysis of the data obtained in the interviews conducted with the students, the content analysis method was used. To test the validity of the data obtained as a result of the analysis, the results of the individual analyses were discussed by the researchers, consensus was reached, and to calculate the rate of agreement, the formula "Agreement = Number of Agreements/(Number of Agreements + Number of Disagreements) X 100" was used, and as a result, it was determined that a rate of agreement of 91% in the analyses related to the students was achieved. This rate is accepted as reliable for research (Miles and Huberman, 1994).

Descriptive analysis technique was used for reliability of the analyses of the data obtained from the reflective diaries. Data were coded separately by two expert coders, inter-rater consistency was examined, and it was seen that they had a rate of agreement of 88%.

With the aim of supporting and increasing the validity of the interviews made with the students, observation was made by the researcher and a mathematics teacher for a total of 20 hours in 5 different classes for 2 lesson periods each. For analysis of the data obtained from the observation form, the descriptive analysis technique was used. For reliability of the analyses, the data were coded separately by two expert coders, inter-rater consistency was examined, and it was seen that they had a rate of agreement of 85%.

IMPLEMENTATION PROCESS

The implementation period of the research lasted for a total of 14 weeks. The experimental applications of the research were carried out in the "Ratios and Proportions" unit by the branch teachers in all three groups. Execution of the instruction in the groups lasted six weeks, excluding the application of the tests. Prior to implementation of the programmes, the MAT and LTST were applied to the groups as the pre-test. While the mathematics instructional design developed according to the AHTI was carried out in the experimental group, the existing programme, in which the traditional expository method and question-answer technique were used, was implemented in the control group. However, different from the control group, a programme enriched with worksheets was carried out in the placebo group. During the implementation process, the qualitative data of the research were gathered with a diversification strategy using three different qualitative data collection techniques. The researcher participated in the instruction process in the experimental group

as an observer, and carried out the structured observation process. Moreover, apart from the researcher, another mathematics teacher also took part in the instruction process as an observer by keeping field notes on the observation form. The reflective diaries kept by the students formed the data sources in the document examination section of the research.

FINDINGS

FINDINGS RELATED TO THE FIRST HYPOTHESIS

One-Way analysis of variance Results for the Mathematics Achievement Pre-test scores of the groups are given in Table 2.

Table 2. One-way Analysis of Variance for Pre-test Scores of Groups in MAT

Source of Variance	Total Squares	sd	Mean Squares	F	p
Between Groups	313.037	2	156.519	.688	.506
Within Groups	19350.679	85	227.655		
Total	19663.716	87			

As a result of the analysis, no statistically significant difference ($F_{(2-85)}$=.688, p>.05) was observed between MAT pre-test mean scores of participants in the experimental group ($\bar{X}$=32.60), the control group ($\bar{X}$=37.20), or the placebo group ($\bar{X}$=35.60).

To examine whether there was a difference between pre-test and post test scores of the three groups in the MAT, the groups' mean scores were compared using one-way analysis of variance. The results of analysis are given Table 3.

Table 3. One-way Analysis of Variance of Differences in Pre-test and Post test Scores of Groups in MAT

Source of Variance	Total Squares	sd	Mean Squares	F	p	η^2
Between Groups	2681.885	2	1340.942	3.747	.028	.08
Within Groups	30416.831	85	357.845			
Total	33098.716	87				

As a result of the analysis, a statistically significant difference ($F_{(2-85)}$=3,747, p>.05) was observed between MAT mean scores of participants in the experimental group ($\bar{X}$=27.54), the control group ($\bar{X}$=14), and the placebo group ($\bar{X}$=21.73). Moreover, as a result of the Scheffé multiple comparison test that was performed, a statistically significant difference was found between the experimental group and control group in favour of the experimental group. According to the test result, the effect size (η^2=,08) is medium level.

To examine whether there was a difference between post-test and retention test scores of the three groups in the mathematics achievement test, the groups' mean scores were compared using one-way analysis of variance. The results of analysis are given Table 4.

Table 4. One-way Analysis of Variance of Differences in Post-test and Retention Test Scores of Groups in MAT

Source of Variance	Total Squares	sd	Mean Squares	F	p
Between Groups	358.092	2	179.046	.542	.584
Within Groups	28113.181	85	330.744		
Total	28471.273	87			

As a result of the analysis, no statistically significant difference ($F_{(2-85)}$=.542, p>.05) was observed between MAT mean scores of participants in the experimental group ($\bar{X}$= - 4.71), the control group ($\bar{X}$= - 4), or the placebo group ($\bar{X}$= .13). The findings reveal that there was a non-significant decrease in mean scores of all groups.

Accordingly, to determine whether there was a difference between MAT post-test and retention test scores within the groups themselves, mean scores of each group were compared using t-test for dependent groups. The results of analysis are given Table 5.

Table 5. Dependent Groups T-Test Analysis of Differences between MAT Post-test and Retention Test Scores of Experimental, Control and Placebo Groups

Measurement	Group	N	$\bar{X}$	S	sd	t	p
Post-test	Experimental	28	60.14	14.42	27	1.35	.190
	Control	30	51.20	17.34	29	1.11	.276
	Placebo	30	57.33	19.01	29	.45	.964
Retention Test	Experimental	28	55.43	20.45	27	1.35	.190
	Control	30	47.20	19.12	29	1.11	.276
	Placebo	30	57.20	20.72	29	.45	.964

As a result of the t-test for the experimental group, a statistically significant difference was not observed ($t_{(27)}$=1.35, p>.05) between MAT mean scores in the post-test ($\bar{X}$= 60.14) and retention test ($\bar{X}$= 55.43). A non-significant decrease was seen between mean scores in the post-test and retention test for the experimental group. As a result of the t-test for the control group, a statistically significant difference was not observed ($t_{(29)}$=1.11, p>.05) between mean scores in the post-test ($\bar{X}$= 51.20) and retention test ($\bar{X}$= 47.20). The t-test result for the placebo group did not reveal a statistically significant difference ($t_{(29)}$= .45, p>.05) in mean scores for the post-test ($\bar{X}$= 57.33) and retention test ($\bar{X}$= 57.20).

To examine whether there was a difference between retention test scores and retention monitoring test scores of the three groups in the MAT, the groups' mean scores were compared using one-way analysis of variance. The results of analysis are given Table 6.

Table 6. One-way Analysis of Variance of Differences in Retention Test and Retention Monitoring Test Scores of Groups in MAT

Source of Variance	Total Squares	sd	Mean Squares	F	p	η^2
Between Groups	1583.640	2	791.820	3.306	.041	.07
Within Groups	20356.724	85	239.491			
Total	21940.364	87				

As a result of the analysis, a statistically significant difference ($F_{(2-85)}$= 3,306, p>.05) was observed between MAT mean scores of participants in the experimental group ($\bar{X}$=10.57), the control group ($\bar{X}$=1.60), and the placebo group ($\bar{X}$=1.33). Moreover, as a result of the Scheffé multiple comparison test that was performed, a statistically significant difference was found between the experimental group and control group, and the experimental group and placebo group, in favour of the experimental group. The test result reveals that the calculated effect size (η^2=.07) is medium level. The changes in the groups' MAT mean scores are shown in Fig. 1.

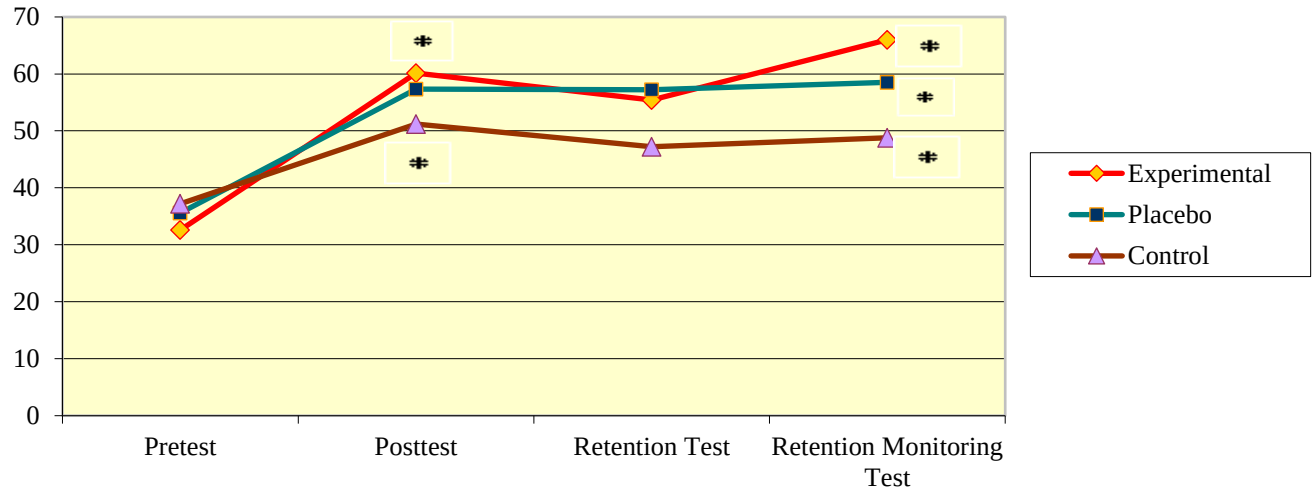

Figure 1. Changes in MAT Mean Scores of Groups
(* Groups between which there were significant differences in mean scores)

To examine whether there was a difference among the LTST scores of the groups selected for the experimental design, the mean pre-test scores of the groups were compared using one-way analysis of variance. The results of analysis are given Table 7.

Table 7. One-way Analysis of Variance for Pre-test Scores of Groups in LTST

Source of Variance	Total Squares	sd	Mean Squares	F	p
Between Groups	.044	2	.22	.23	.977
Within Groups	80.274	85	.944		
Total	80.318	87			

As a result of the analysis, no statistically significant difference ($F_{(2-85)}$=.23, p>.05) was observed between LTST pre-test mean scores of participants in the experimental group ($\bar{X}$=1.32), the control group ($\bar{X}$=1.30), or the placebo group ($\bar{X}$=1.26).

To examine whether there was a difference between pre-test and post-test scores of the three groups in the LTST, the groups' mean scores were compared using one-way analysis of variance. The results of analysis are given Table 8.

Table 8. One-way Analysis of Variance of Differences in Pre-test and Post-test Scores of Groups in LTST

Source of Variance	Total Squares	sd	Mean Squares	F	p	η^2
Between Groups	18.306	2	9.153	8.502	.000	.17
Within Groups	91.512	85	1.077			
Total	109.818	87				

As a result of the analysis, a statistically significant difference ($F_{(2-85)}$=8.502, p>.05) was observed between LTST mean scores of participants in the experimental group ($\bar{X}$=2.11), the control group ($\bar{X}$=1.03), and the placebo group ($\bar{X}$=1.27). The test result shows that the effect size (η^2=,17) is large. Moreover, as a result of the Scheffé multiple comparison test that was performed, a statistically significant difference was found between the experimental group and control group, and the experimental group and placebo group, in favour of the experimental group.

Accordingly, to determine whether there was a difference between LTST pre-test and post-test scores within the groups themselves, mean scores of each group were compared using t-test for dependent groups. The results of analysis are given Table 9.

Table 9. Dependent Groups T-Test Analysis of Differences between LTST Pre-test and Post-test Scores of Experimental, Control and Placebo Groups

Measurement	Group	N	$\bar{X}$	S	sd	t	p
Pre-test	Experimental	28	1.32	.94	27	10.51	.000
	Control	30	1.30	.99	29	1.11	.276
	Placebo	30	1.27	.98	29	7.35	.000
Post-test	Experimental	28	3.46	1.57	27	10.51	.000
	Control	30	2.30	1.91	29	1.11	.276
	Placebo	30	2.53	1.76	29	7.35	.000

As a result of the t-test for the experimental group, a statistically significant difference was observed ($t_{(27)}$=10.51, p>.05) between LTST mean scores in the pre-test ($\bar{X}$= 1.32) and post-test ($\bar{X}$= 3.46). The test result reveals that the calculated effect (d= 1.99) is at a very high level. As a result of the t-test for the control group, a statistically significant difference was not observed ($t_{(29)}$=1.11, p>.05) between mean scores in the pre-test ($\bar{X}$= 1.30) and post-test ($\bar{X}$= 2.30). As a result of the t-test for the placebo group, a statistically significant difference was observed ($t_{(29)}$=7.35, p>.05) between mean scores in the pre-test ($\bar{X}$= 1.27) and post-test ($\bar{X}$= 2.53). The test result shows that the calculated effect (d= 1.34) is at a very high level. The changes in the groups' LTST mean scores are shown in Fig. 2.

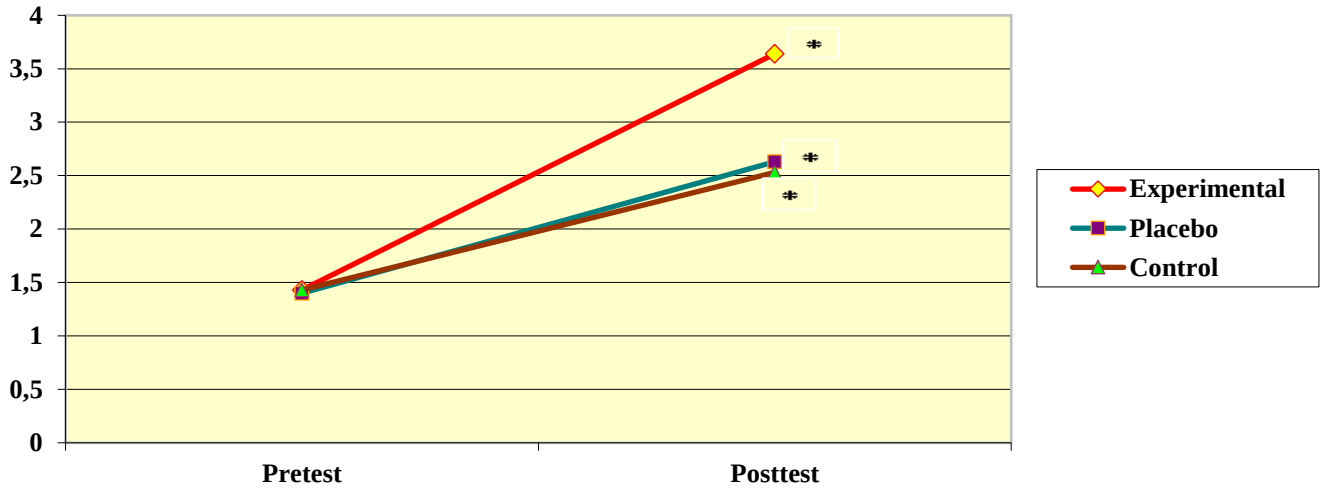

Figure. 2. Changes in LTST Mean Scores of Groups
(* Groups between which there were significant differences in mean scores

To examine whether there was a difference between science achievement test (SAT) scores of the three groups in the SAT, the groups' mean scores were compared using one-way analysis of variance. The results of analysis are given Table 10.

Table 10. One-way Analysis of Variance for Pre-test Scores of Groups in SAT

Source of Variance	Total Squares	sd	Mean Squares	F	p	η^2
Between Groups	2581.610	2	1290.805	9.787	.000	.19
Within Groups	11210.390	85	131.887			
Total	13792.000	87				

As a result of the analysis, a statistically significant difference ($F_{(2\text{-}85)}$=9.787, p>.05) was observed between SAT mean scores of participants in the experimental group ($\bar{X}$=44.57), the control group ($\bar{X}$=37.17), and the placebo group ($\bar{X}$=31.23). The test result shows that the effect size (η^2=,19) is large. Moreover, as a result of the Scheffé multiple comparison test that was performed, a statistically significant difference was found between the experimental group and control group, and the experimental group and placebo group, in favour of the experimental group. According to these data, the instructional design based on the AHTI can be considered to have had a positive effect on the experimental group's achievement of outcomes in the "Mirrors" unit.

The SAT, which was developed to examine the possible effects of the AHTI on the achievement of outcomes of students in the experimental group in the unit named "Mirrors", was also applied to designated students to determine whether or not students in the experimental group used the stages of the Landamatics algorithm, which they learned in the unit named "Ratios and Proportions" in different disciplines. The results of analysis are given Table 11.

When the findings are examined, student behaviours arising from the structure of the questions in the test - reading the problem out loud, explaining the problem in writing, giving reasons, etc.- were observed and behaviours such as attempting to recreate the problem, dividing the solution into stages, transferring the skill, and reorganising the information, were also observed. Moreover, it was seen that in the process of solving certain problems, students in the upper group avoided displaying behaviours related to algorithmic thinking by giving quick responses to the questions, whereas students in the lower group displayed behaviours related to algorithmic thinking.

Based on the findings, the interpretation can be made that while attempting to solve the test given to them out loud, the students analysed the data given in the problem, organised the data by reviewing their existing knowledge, created solutions according to the situation, explained their reasons related to the solutions by writing them down, adapted their mental skills to new situations, and organised and reorganised the information.

Table 11. Students' Levels of Using Landamatics Algorithm

Landamatics Steps	Cognitive Process	Student Behaviours	f	Upper Group Lower Group
Mental Processes Guiding the students to discover the system of mental operations	Thinking about the problem	Reading the problem out loud	42	21 21
		Repeating the data given in the problem	9	4 5
		Writing the data given in the problem	5	3 2
		Drawing a diagram to discover the data given in the problem	2	2 0
		Total	58	30 28
			f	Upper Group
Assisting the students in becoming aware of what they do in their minds when performing a task and then formulating a method that goes with it.	Awareness of one's own thought processes	Giving reasons for the solution	33	17 16
		Analysing the data given in the problem	15	9 6
		Reviewing their knowledge	10	6 4
		Total	58	32 26
Assisting the students in learning to apply the discovered method.	Deciding how the knowledge will be used	Organising their knowledge for the solution	20	11 9
		Creating options for the solution	14	10 4
		Organising the options	14	10 4
		Eliminating options	14	10 4
		Total	62	41 21
			f	Upper Group
Assisting the students in internalising the discovered method.	Generating appropriate solutions for the problem situation	Explaining the solution by writing it	33	19 14
		Explaining the solution by drawing it	13	9 4
		Attempting to recreate the problem	7	5 2
		Performing an operation	6	4 2
		Making a comparison	6	4 2
		Dividing the solution into stages	2	2 0
		Total	67	43 24
			f	Upper Group
Assisting the students in automising the discovered method.	Transferring the knowledge to new situations	Transferring the skill	6	4 2
		Total	6	4 2
			f	Upper Group
Evaluating whether the intended degree of generalisation has been achieved	Checking achievement and accuracy of the solution	Reorganising the information	2	1 1
		Total	2	1 1

FINDINGS RELATED TO THE FIRST SUB-PROBLEM

FINDINGS OBTAINED FROM THE INTERVIEWS HELD WITH THE STUDENTS

When the findings obtained as a result of the content analysis of students' views, expressed in the interviews, about what the subject of mathematics reminded them of and about the importance of this subject for them are examined; it is seen that the responses given by the students are grouped under the themes of "Things Evoked by the Subject of Mathematics" and "Importance of the Subject".

In the theme of Things Evoked by the Subject of Mathematics, in response to the question "What does mathematics remind you of?" answers were given by the students as "related to daily life", "operations", "numerical logic", "intelligence" , "reasoning" , "shopping" and "difficulty" of students.

In the theme of Importance of the Subject, the subject of mathematics was regarded as important by the students due to its "effect on high school placement score", "relationship with other subjects" and "necessity for lessons" of students.
Based on these indications, it can be said that, albeit for different reasons, students regarded the subject of mathematics as important.
When the findings obtained as a result of the content analysis of students' views about their expectations from the subject of mathematics and about the degree of fulfillment of their expectations are examined; it is seen that the responses given by the students are grouped under the themes of "Expectations from the Subject of Mathematics" and "Degree of Fulfillment of Expectations".
In the theme of Expectations from the Subject of Mathematics, in response to the question "What are your expectations from the subject of mathematics?" answers were given by the students as "a different experience", "anxiety", "high expectation", "low expectation" and "exciting" of students.
In the theme of Degree of Fulfilment of Expectations, answers were given by the students as "enjoyable", "effective", "facilitating", "permanent", "attention-grabbing", "appealing", "participatory" and "absorbing" of students as measures of the extent to which their expectations were fulfilled.
Based on these indications, it can be said that although the students had different expectations from the subject of mathematics before the instruction process began, when the lessons were over, the expectations of students with positive expectations were fulfilled, while the expectations of students who had lower expectations and who felt anxious were fulfilled in a more positive way than they had expected.
When the findings obtained as a result of the content analysis of students' views about the differences between this lesson and the mathematics lessons taught previously are examined; it is seen that the responses given by the students are grouped under the theme of "Differences in Instruction of the Subject".
It can be seen that regarding differences noticed by the students in instruction of the subject compared to their previous mathematics lessons, the instruction was found to be "enjoyable", "different", "effective", "facilitating", "permanent", "motivating", "attention-grabbing", "appealing", "exciting", "participatory" and "absorbing" of students.
When the findings obtained as a result of the content analysis of students' views about the contribution made by the algorithm used in the subject of mathematics and of the activities carried out in class are examined; it is seen that the responses given by the students are grouped under the theme of "Contribution Made".
Examining students' views related to the methods, techniques and activities applied in the teaching of the lessons, the activities were found to be effective, to play a facilitating role in learning, to be useful, to be a guide for problem solving , to make learning permanent of the students; and to enable quick thinking in problem solving, effective participation in in-class activities, group activities and cooperation in learning, logical thinking in problem solving and faster learning of the students.
In line with these findings, it can be said that the methods, techniques and activities applied in the lessons made a positive contribution to students' performance in the subject of mathematics.
When the findings obtained as a result of the content analysis of students' views about making the subject of mathematics more effective are examined; it is seen that the responses given by the students are grouped under the theme of "Making the Subject More Effective". In order to make the subject of mathematics more effective, it was suggested that the model should be applied in other school subjects, that the model should be applied in other topics, that the implementation of the programme should be continued and that the model should be applied over a longer period on the students.
In line with these findings, it can be said that in order to make the subject of mathematics more effectively, students wanted the programme to be implemented in other school subjects and in other topics of mathematics, and wanted the programme to be extended over a longer period.

FINDINGS OBTAINED FROM THE STUDENTS' REFLECTIVE DIARIES

When the result of the descriptive analysis of the notes taken by the students in the experimental group in their diaries, regarding the instructional design that was applied based on the AHTI, findings related to how the lessons went are examined; it can be said that the students enjoyed the activities, and that they found them good/very good and enjoyable, but that some students, albeit few in number, sometimes did not enjoy the activities and had difficulty with the activities especially in the evaluation sections.

When the result of the descriptive analysis of the notes taken by the students in their diaries, findings related to the things that the students did in the lessons are examined; it can be said that during the activities in the lessons, the students performed numerical operations, answered the questions asked by the teacher, took part in the activities in the lessons, and enjoyed themselves in the activities, although some students, albeit few in number, were bored and had difficulty during the activities. It this context, it can be said that the instructional design based on the AHTI included students in the lessons by making them active.
When the result of the descriptive analysis of the notes taken by the students in their diaries, findings related to students' views on their performance during the lessons are examined; it is seen that the students mostly found their performances in the activities to be good/very good, and that they participated actively in the activities. It can be said that the instructional design based on the AHTI enabled the students to regard their performances as adequate.

FINDINGS RELATED TO THE SECOND SUB-PROBLEM

FINDINGS OBTAINED FROM THE RESEARCHER'S FIELD NOTES

When the result of the descriptive analysis of the researcher's observation of students in the experimental group, findings related to students' behaviour during the implementation are examined; it can be said that the activities in the mathematics lessons conducted according to the AHTI attracted the attention and aroused the curiosity of the students, motivated them, directed them towards inquiry, collaboration and investigation, increased their efforts, and sometimes made the subject entertaining. However, in the sections of the lessons named *Evaluating whether the intended degree of generalisation has been achieved*, it was observed that some students, albeit few in number, were unwilling/bored, and that a few students also had difficulty. The fact that some evaluation activities in this section were difficult for several students since they were unable to focus on the process can be given as a reason for this.

FINDINGS OBTAINED FROM THE TEACHER'S FIELD NOTES

When the result of the descriptive analysis of the branch teacher's observation of students in the experimental group, findings related to students' behaviour during the implementation are examined, it can be said that the activities in the mathematics lessons conducted according to the AHTI attracted the attention and aroused the curiosity of the students, motivated them, directed them towards inquiry, collaboration and investigation, increased their efforts, and sometimes made the subject entertaining. Furthermore, although some students sometimes had difficulty in expressing the operations mathematically and behaved unwillingly in the sections of the lessons named *Assisting the students in becoming aware of what they do in their minds when performing a task and then formulating a method that goes with it*, they discovered the operations with the support of the teacher. In the sections of the lessons named *Evaluating whether the intended degree of generalisation has been achieved*, it was also observed that some students, albeit few in number, were unwilling/bored, that some students only partially took part in the lessons, and that some students needed the support of the teacher due to having difficulty. The fact that some evaluation activities in this section were difficult for several students since they were unable to focus on the process can be given as a reason for this.

CONCLUSION AND DISCUSSION

The quantitative findings of the study related to the students' mathematics achievement reveal that the experimental algorithm was effective on students' mathematics performance and that the mathematics instructional design developed according to the AHTI had a significant effect on experimental group students' mathematics achievement post-test mean scores compared to those of students in the control group. In the study he conducted to determine the effect of mathematics instruction based on the AHTI, Landa (1995, p. 44) concluded that students' problem-solving competences increased significantly. Similarly, Rufi'i (2015, p. 942) investigated the effectiveness of AHTI-based instruction on development of preservice teachers' academic achievement, and found that the implementation increased the students' academic achievement. On the other hand, the findings reveal that no statistically significant difference was found between mathematics achievement post-test and retention test mean scores of the experimental, control and placebo groups, and that there was a non-significant decrease in mean scores of all groups. The fact that during the implementation period, students in the experimental group had their mid-year holiday

for two of the four weeks between the post-test and the retention test, can be counted among the reasons for this decrease in scores. In fact, a certain decrease in retention test scores is an expected result. The non-significant decrease in scores between post-test and retention test shows that although students in the experimental group were on holiday, they did not forget the applications in the instruction process based on the AHTI. However, the findings reveal that there was a statistically significant difference between mathematics achievement retention test and retention monitoring test mean scores of the experimental, control and placebo groups, in favour of the experimental group. Al Sheraa and Abdul-kader (2013, p. 24) examined the effect of AHTI-based instruction on achievement of students in the computer department, and as a result of the research, determined that the implementation had a positive impact on students' academic achievement and retention scores. The statistically significant difference found between the groups' retention test and retention monitoring test mean scores in favour of the experimental group can be explained by the fact that the AHTI-based instruction process was designed in a spiral structure. The fact that throughout the instruction process, the algorithms included in the teaching plans and the concepts they included were repeated when the occasion and need arose, and were used again in the evaluation activities, played an effective role in the retention of learning in students in the experimental group.

When the qualitative findings of the study related to students' mathematics performance are examined, it is seen that results corresponding to the quantitative findings were obtained. In the interviews made with the students, by stating that they regarded the subject of mathematics as important and that their expectations from the subject of mathematics were positively fulfilled, students related these to their academic achievement. By finding the instruction of the lessons entertaining, different, effective and facilitating, and recognising that this was different to that of their previous mathematics lessons, students were able to develop a positive attitude towards the applications carried out in class. In parallel with this, the fact that students stated that the algorithm used and the activities carried out in the lessons made a positive contribution to their mathematics performance, reveals that they considered themselves successful in this subject. With regard to geometry instruction, it was seen that AHTI-based learning environments were evaluated as entertaining and enjoyable by students, and that they contributed to effective assimilation and interpretation of the topics by students (Çırakoğlu and Vural, 2016, p. 156). Similarly, it was stated that a blended learning environment, based on the AHTI increased students' academic achievement regarding skills for preparing presentations, had a positive effect on attitudes towards lessons, and increased levels of motivation (Aygün, 2011, p. 73). Furthermore, in the diaries that they kept, students stated that they enjoyed the activities conducted in class in a number of aspects. They found the mathematics instructional process conducted according to the AHTI to be excellent, appealing and enjoyable; and by mostly evaluating their performances in the activities as good, they considered themselves to be active participants. Similarly, the results of the observations related to students' behaviours reveal that activities carried out increased students' efforts, developed their inquiry, collaboration and investigation skills, and sometimes made the subject entertaining. In one of a limited number of studies examining students' views and behaviours in an AHTI-based learning environment, Landa (1998, p. 34) determined that the activities in an implementation carried out in a geometry class went very well, that the students grasped the implementation process very well, and that they learned how to implement this process themselves. On the other hand, it is striking that some students, though few in number, held the view that they sometimes did not enjoy the activities and grew bored in the activities, and that they had difficulty especially in the activities in the evaluation sections. This situation shows a parallel with the observation results. It was seen that especially in the activities in the evaluation sections of the lessons, some students, though few in number, were unwilling/bored, and that some students also needed the support of the teacher due to having difficulty. The main reason for this situation is the fact that these students' levels of readiness were low. When the pre-test results of the few students who were bored, behaved unwillingly and had difficulty in the implementation process were examined, it was determined that the students' basic mathematics knowledge was poor. The views and observation findings of the practising teacher are such as to support this result. In this context, Tall (1992, p. 5) revealed some of the reasons for learning difficulties determined in mathematics to be inadequate knowledge of basic mathematics, inability to transform verbal expressions into mathematical symbols and lack of knowledge of algebra, geometry and trigonometry. Moreover, Tall and Razali (1993, p. 220) emphasised that some students experienced a series of difficulties in using concepts and coordinating operations.

The findings related to the students' science achievement test reveal that the experimental algorithm was effective on students' science performance and that the mathematics instructional design developed according to the AHTI had a significant effect on the science achievement post-test mean scores of students in the experimental group compared with those of students in the placebo and control groups. In a study conducted with the aim of determining the effect of physics instruction based on the AHTI, and different from the existing teaching programme, elementary school students' ability to solve more than 40% of problems with medium and advanced levels of difficulty was tested, and it was determined that the students solved 88% of the problems (Landa, 1995, p. 44). Moreover, it was found that students specified for the aim of determining whether or not students in the experimental group used the stages of the AHTI algorithm, which they learned in the unit named "Ratios and Proportions", in different disciplines, solved the science achievement test individually by reasoning out loud, and when the findings obtained from the findings obtained from the images recorded in the videos were examined, similar results to the quantitative findings were obtained. Distinctive cognitive behaviours, such as attempting to recreate the problem, dividing the solution into stages, transferring the skill, and reorganising the information, were observed in the students. In this context, Landa (1998, p. 34) argued that the AHTI allows students to internalise the thought processes and steps of understanding that they need to use when they are learning something new, and that by enabling learners to develop their general thought processes, it teaches them to understand information better and transfer knowledge to new situations. On this point, Landa (1998, p. 4) asserted that the theory gives importance to how students need to think and to their awareness of their own thought processes. In this context, it is seen that the students displayed behaviours related to algorithmic thinking while solving certain problems.

The quantitative findings of the study reveal that the experimental algorithm was effective on students' logical thinking skills and that the mathematics instructional design developed according to the AHTI had a significant effect on experimental group students' logical thinking skills post-test mean scores compared to those of students in the placebo and control groups. No study can be found in the literature in which a relationship between the AHTI and logical thinking skills is revealed. However, Landa (1998, p. 1) stated that the reason why many students experience problems in being able to solve similar problems to the ones that they learn is that a general reasoning method is not taught to students as an instructional system, and argued that the AHTI approach creates reliable, scientific, concept-compatible generalisations different from the empirical generalisations that form in the student's mind. On this point, it is striking that there is a direct connection between logical thinking skills and the reasoning method specified by Landa.

To sum up, the quantitative and qualitative findings of the study reveal that under the effect of the mathematics instructional design developed based on the AHTI, students in the experimental group increased their success in mathematics and science, and their logical thinking skills were also positively affected. The obtained results show similarity with theoretical explanations on this subject field (Landa, 1974, 1984, 1987, 1995 and 1998) and the results of the majority of studies conducted in the literature (Landa, 1995, 1998; Leff, 2004; Aygün, 2011; Al Sheraa et. al., 2013, p. 24; Rufi'i, 2015).

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