Original Article

Investigating the Effect of Teaching Mathematics based on Bruner Theory on Eighth-Grade Male Students' Misconceptions in Equation Solving

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Abstract

Considering that the topic of equation plays a very important role in solving mathematical problems and other sciences including physics and chemistry, and is a prerequisite for more mathematics courses at higher levels, it is an essential concept for students to learn it. This study aimed at reviewing the causes of common misconceptions among eighth-grade male students in district 16 of Tehran in the field of equation solving and providing instructions to address the misconceptions and promote their education based on Bruner theory. The statistical population of the study consisted of 1730 male students in eighth-grade, who were studying in the academic year 2015-2016. A sample of 314 students was selected cluster randomly from this population. In the first phase, 36 questions were designed according to the table of identified misconceptions (18 cases), and finally 27 questions were selected according to the validity and reliability of the questions (Cronbach's alpha coefficient of 0.751). A teaching method was designed based on Bruner's theory along with the warning of misconception for the testing group, in order to address and prevent the misconceptions. The control group was taught based on the traditional teaching method. The previous test was re-performed on two groups to collect the statistical data. Data were analyzed using independent t-test and covariance. The results showed that the teaching method based on Bruner's theory has been effective in addressing and reducing many misconceptions.

Keywords: Students' Misconception, Equation Solving, Teaching Mathematics, Bruner Theory

INTRODUCTION

Misconceptions are not just an accidental mistake, they are a form of a well-formed mental structure of incomplete ideas [1]. Drew (2005), on the other hand, defined misconception as a misuse of a procedure, a mis-generalization, or a different understanding of a situation [2]. Misconceptions are systematic with a solid structure, which are not easily corrected. In his opinion, a person with a mistake can realize his mistake with a slight change, and correct it, but someone who has a misconception, justifies his mistake.

Misconceptions usually occur when, in particular, ideas are created in the student's mind and then the student generalizes these ideas incorrectly [3]. In the planning of the curriculum as well as other sciences including physics and chemistry, it is necessary for students to make and solve equations. In solving a problem, usually an equation is needed, so students need a strong understanding of the equations. However, research showed that many students have problems in understanding and solving equations. Therefore, more research is needed to identify and analyze the mistakes of students and teachers in the early stages of learning and teaching algebra and equations [4].

Lima and Tall (2006) believed that the equation is at the center of algebra and is somehow intertwined with arithmetic, so the equations and their solutions have a special place in school mathematics [5]. The equation is an abstract concept, for which, several stages of abstraction are required to form it, so at each stage of the concept, there may be a conflict between the concepts formed in the students' minds and the

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concepts to be learned. This leads to widespread conceptual errors in this topic [6].

Bruner provided the theory of exploratory learning, since he believed that an educational theory should answer the question of how to learn better and not confront the learner with his knowledge, but instead show him the problem so that he can discover the relationships between the tasks and the solutions. His emphasis was on exploratory learning. Bruner`s intention regarding exploratory meaning was that "it is any kind of knowledge that the child reaches using his or her own ideas". Note that Bruner was more in favor of guided exploration than fully independent exploration. Guided exploration is a kind of exploration that is supported or guided by knowledgeable individuals [7]. In addition to being a cognitive development theory, Bruner's theory is also a cognitive theory of learning. Familiarity with misconception makes it possible to find a clearer understanding of what mathematical misconception is. Therefore, considering the importance of concepts in mathematics in this study, it was attempted to identify the causes of common misconceptions among students in solving the equation in eighth-grade students and then take steps to improve and reduce these misconceptions using Bruner exploratory theory.

Theoretical Foundations of Research

Algebraic misunderstandings

Considering the fact that students are firstly introduced with algebraic concepts, patterns, variables, and algebraic expressions before the concept of equation, algebraic misunderstandings can give rise to the solution of equation misunderstandings. Matz (1982, quoted in Karimi Kia, 2012) [6] believed that the most common mistakes in algebra are mainly happened for two reasons:

1. Inappropriate application of a specific rule into the new position (incorrect replacement)
2. Incorrect adoption of a specific law to solve a new problem (error in induction). like $(a+b)^2=a^2+b^2$, which is mostly caused by error in induction.

From the viewpoint of Agnieska (1997, cited by Karimi Kia, 2012) [6], one of the things that misleads students in understanding the meaning of algebraic expressions and symbols is the use of real objects. He argued that, for example, it may be efficient to use real objects for 8a (8 apples) algebraic expressions or 2a+3a (sum of 2 apples with 3 apples), but how can students generalize to provide a good interpretation for -5a+2a?

The third international study of mathematics and science (TIMSS, 1998) has shown that students have difficulty not only in understanding letters as variables, but also in solving algebraic equations and transforming verbal problems into algebraic, which this is a particular concern. Therefore, algebra plays a pivotal role in school mathematics (National Council of Teachers of America, 2000 cited in Warren 2004) [8].

Much of students' misunderstandings about mathematics, date back to their mental schemas and how they are formed and expanded, and it is often seen that the schemas created by students are not coherent. Therefore, conceptual errors or misunderstandings cannot be attributed solely to their lack of focus, carelessness and the like, but should search their root in the schema of one's mind [9].

In the viewpoint of Keazer (2004), misunderstanding can heal like an illness if diagnosed early and student’s perception from mathematic conception can be reconstructed [10]. Actually, considering the right solution cannot correct the misunderstanding, rather it is necessary for students to apperceive the skilled conception which can be replaced with their incorrect alternatives and the mental schema should be reconstructed. The word reconstruction means that incorrect conception should be wangled by contrast to correct conception and be reconstructed from the way of replacement. Vigotsky believed that for collation to misunderstandings, beginner learner should be under administration of a specialist. Piazhe also agreed him in this way and believed that student’s learning should take place under the guide of a teacher.

Brunner Theory`s Method

Bruner is one of the major critics of the behaviorist approach in learning. In his point of view, predetermined programs lead the learner to follow the incontestable programs and prevent him from being creative. In his view, what is happening in the classroom today, teaches some meaningless concepts that the learner keeps them in mind in a passive and parroting way [11]. In the year 1966, Jerome Bruner played an important role in introducing exploratory learning as one of the most well-known cognitive paradigms which was based on constructivism (Gayer, 2004, quoted by Razavi, 2007) [12].

Bruner believed that instead of transferring information and facts to the learners, they should be placed in situations where they can discover themselves (Clarke, 2000, quoted by Razavi, p. 53) [12]. From the Brunner’s point of view, discovery is a kind of thinking that comes in the way that one transcends the existing information and reaches new insights (Biller, 1990, cited by Kadivar, 2011) [11]. So, Bruner considered discovery learning as an innovation and necessity to be replaced with parrot learning, which restricted thinking.

Bruner claimed that teaching that relies on construction (which is a key feature of his discovery method) makes the subject more comprehensible, minimizes forgetting, increases the chances for transfer, and improves student progress through the levels. Elementary knowledge at higher levels makes this issue much easier. He also believed that this is the best way to encourage the most complete way of thinking, that is, normal thinking, and ultimately, this type of teaching leads to intuitive understanding, an understanding that is not only pleasing to the student, but also, it highly increases self-esteem and confidence (Biller, quoted by Kadivar, 2011) [11]. Each subject can be taught to any child at any level of age development as appropriate to his/her intellectual and age competence [13].

Here is an outline of the educational applications of Brunner's theory:

1. Bruner believed that by adapting educational methods to the level of children's cognitive functioning, they can teach them any subject that can be taught to adolescents and adults [7]. Any subject can be taught to any child at any stage of development [13]. Bruner viewed the child as a small-scale expert. In his opinion, the child is able to understand the operation of disciplines at almost any age. In his view, the difference between a child's cognitive processes with an adult is manifested in the quantity rather than type and quality [14].
2. Every area of knowledge can be represented as one of three motor, visual and symbolic systems. Teaching any particular subject to any particular individual requires one of the three systems. In general, Bruner proposed that it is better for the teacher to present his / her education in all three practical, visual and symbolic systems, where possible [7].
3. Bruner is a defender of the guided discovery method rather than fully independent discovery method. Guided discovery is a way in which learners are encouraged to understand and realize the questions with the guidance of the teacher [15].
4. Encouraging students to get the core of the subject: According to Bruner, discovery is an internal thought and process. Bruner believed that such an internal process involves the reorganization of the thinking system. To do this, students should be encouraged to learn the fundamentals of a subject or area of knowledge [11].
5. The learning environment should be quite calm and free from anxiety and stress. Educational conditions should be designed in such a way that students can express their ideas freely, think about different issues, and organize their mental concepts in order to strengthen their thinking power [16].

Algebraic and arithmetic thinking

Arithmetic objects consist of numbers and algebraic objects include variables, expressions, and equations (Stacey, quoted by Asghari, 2009) [17]. Some past researches, such as Capraro and Joffrion (2006), have shown that students at an early age, have misunderstandings in their arithmetic knowledge and familiarity with arithmetic operators, and these misunderstandings, in later years, prevent them from developing algebraic thinking [18]. In this regard, Booth (1984) stated that many of the problems of students in elementary algebra are rooted in computation and computational operators such as inverse, symmetric [19], participatory, and displacement, which according to Watson (1990) are the basis of it and shape students' problems [20].

Regarding the misunderstandings of students in algebra, there are some inaccurate generalizations that they make in a new context. For example, by referring to simplifying the expression 3+3x+1 and reaching to the 6x answer, such misunderstandings are attributed to the fact that students generalize arithmetic as a false algebra, which have been mentioned as the new learning. [21]. The reason behind is that students' previous schema of arithmetic have not been associated with algebraic sums of similar sentences (new learning), the equivalence of two expressions and two equations. Students in an arithmetic environment usually solve problems in order to generate numerical answers. This also causes some students to dismiss the answer as an algebraic problem when answering a problem [22].

Vance (quoted by Kriegler, 2001) stated that "algebra is sometimes defined as a language for generalizing accounts [23]. In any case, algebra is more than just a set of rules for using the symbols; it is a way of thinking". This way of thinking is considered algebraic thinking whose quality is the greatest factor in the success of students in algebra (Brown and Herbert as quoted by Kriegler, 2001) [23].

Research Methodology

The present study was applied in terms of purpose. The current study`s design was based on two experimental and control groups using pre-test and post-test. In this study, the topic of Eighth Basic Equation was taught in a textbook based on a lesson based on Brunner's heuristic theory. For this purpose, at first, a test was conducted according to the identified misunderstanding made by the researcher to collect the students' misconceptions and its validity and reliability were assessed and the students' misconceptions were identified by this test. Then, the two experimental and control groups were selected from the students who had the most misconception in solving the equation. Then the control group was taught for 6 sessions in the traditional way without mentioning the misunderstandings and 6 sessions in the experimental group was done by Brunner heuristic with an emphasis on the misunderstandings and then the post-test between the two groups was administered to measure their performance.

The statistical population of this study included male students at 8th grade (first grade of guidance school) of district 16 in Tehran. In the first stage, some high schools of the target community were selected randomly clustered. Based on Morgan's table and Charles Cochrane's relation, 314 students were selected accordingly and in the second stage 50 students who had the most misunderstandings, were randomly clustered and placed into two experimental and control groups. In this study, a 27-item researcher-made test was used to collect data and information.

In this study, the content validity of the test was evaluated by one of the mathematics professors at Farhangian University as well as seven of the colleagues who were mathematics teachers. In total, the number of pre-test questions in the first phase was 36 questions. Since the content validity of 9 questions was less than 0.79, these 9 questions were omitted. Cronbach's alpha coefficient of the test was 0.751. Independent t-test was used for data analysis. The level of significance was considered 0.05 and SPSS, version 23, software was also used.

The known misconceptions in this study were as follows:

1. Misconception about the "lack of familiarity with the definition of the equation". Question: 1.
2. Misconception about "variable ignorance". Questions: 2 and 4.
3. Misconception about "understanding variables as spatial value". Question: 3.
4. Misconception about "converting variable to a constant number". Question: 5.
5. Misconception about "not understanding the variable". Questions: 6 and 7.
6. Misconception about "not recognizing the unknown ". Question: 8.
7. Misconception about the "variable should always be written in left". Question: 9.
8. Misconception about "focus on variable x". Question: 10.
9. Misconception about the "equality symbol". Question: 11.
10. Misconception of "verbal conversion of the problem into the equation". Questions: 12 and 13.
11. Misconception about "converting equation to a verbal problem". Question: 14.
12. Misconception related to "converting $ax = b$ into $x = \frac{a}{b}$". Questions: 15, 16 and 17.
13. Misconception about "transferring activities". Question: 18.
14. Misconception about "numerical simplification and algebraic simplification". Question: 19.
15. Misconception about "converting to the simple form of the first-order equation". Question: 20.
16. Misconception about "equivalence". Questions: 21, 22, 23, 24 and 26.
17. Misconception about "fraction operations". Question: 25.
18. Misconception about the "solution of the equation". Question: 27.

Research Questions

First question: Does teaching with the help of Bruner's theory, help reduce and eliminate students' misconceptions?

Second question: Is teaching with the help of Bruner's theory effective in students' equation solving skills?

Results

This study was conducted in district 16 of Tehran. In the first phase, 10 classes were selected from two high schools with a total of 311 students who participated in a researcher-made misconceptions test to identify the misconceptions. In the first section, the data obtained from student responses to the equation were analyzed and studied. The misconceptions in this section were categorized into 18 cases.

Table 1: Descriptive statistics regarding students' misconception scores in the control and experimental groups in the post-test

Group	Number	Mean score of misconception	SD	Minor misconception score	Major misconception score
Control	25	11.48	2.23	7	57
Experimental	25	7.52	1.91	3	37

As Table (1) shows, the mean and standard deviation of the mean score for the control group at post-test was 11.48 and 2.23 and for the experimental group, they were 7.52 and 1.91, respectively. The least misconceptions in the control group were related to the sixth and eighth types and the highest was related to the sixteenth. The lowest misconceptions in the experimental group were those of the second type and the most misconceptions were of the sixteenth type.

According to Chart (1) and Table (2), it seems that teaching based on Bruner's theory, along with pointing out to the identified misconceptions was effective in reducing misconceptions. Table (2) and Chart (1) show the mean decrease in the mean misconceptions of the experimental group compared to the control group.

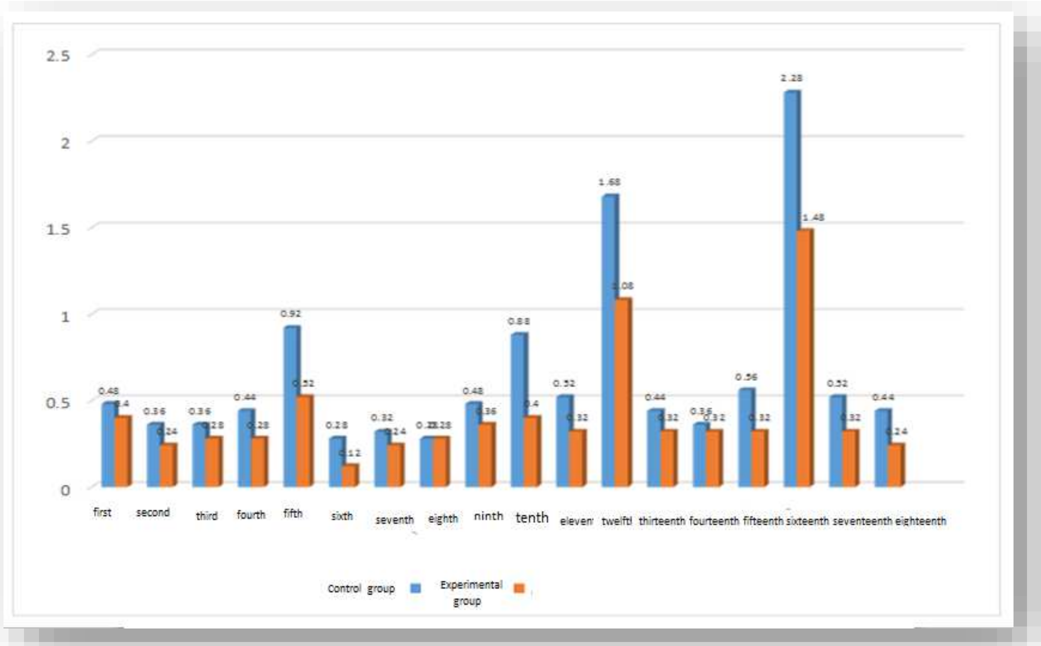

Chart 1: Mean reduction of misconceptions in control and experimental groups.

Table 2: Mean reduction of misconceptions of the experimental group compared to the control group

Type of misconception	The rate of decline in misconception	Type of misconception	The rate of decline in misconception
Sixteenth	0.80	Sixth	0.16
Twelfth	0.60	Ninth	0.12
Tenth	0.48	Thirteenth	0.12
Fifth	0.40	Second	0.12
Fifteenth	0.24	Seventh	0.08
Seventeenth	0.20	Third	0.08
Eighteenth	0.20	First	0.08
Eleventh	0.20	Fourteenth	0.04
Fourth	0.16	Eighth	0

Table (2) identifies the most reduction in the misconception of "converting to the simplest form of the first-order equation", namely, the misconception of the fifteenth type, and shows the least reduction in the misconception of "variable should always be left", which is the eighth misconception.

First, the Leven test was used to test the equality of variance of the two samples.

Table 3: Leven test for homoscedasticity of misconceptions.

Variables	F-ratio	The first degree of freedom	The second degree of freedom	The significance level
Recognition of misconceptions	0.345	1	48	0.560

Considering the P = 0.56 in examining the two groups' variance at the significant level of 0.05, the assumption of the equal variance of the two groups was accepted. The Kolmogorov-Smirnov test was used to evaluate the normality of the misconceptions of the two groups, results of which have been presented in Table (4).

Table 4: Kolmogorov-Smirnov test results

Group	Number	Statistic	Degree of freedom	The significance level of P
Control	25	0.149	25	0.157
Experimental	25	0.161	25	0.093

As can be seen from Table (4), the P-value of the misconceptions in both control and experimental groups was significantly higher than the 0.05 level, which means that the types of misconception scores were normal.

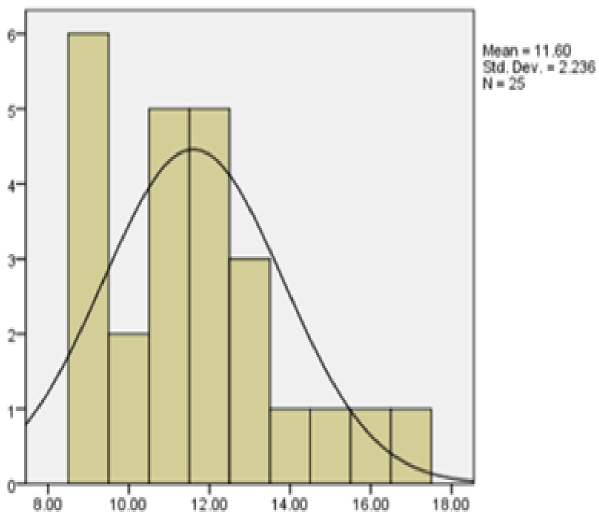

Figure 2. Normal distribution of misconceptions in the control group

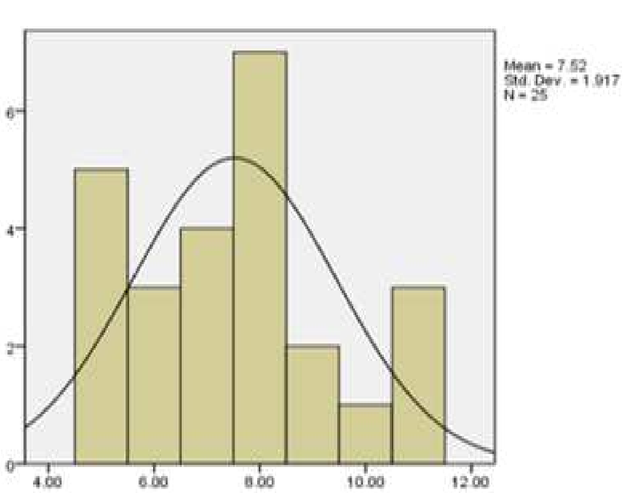

Figure 3. Normal distribution of misconceptions in the experimental group

Since the data of both samples had a normal distribution and equal variance, the t-test of independent samples was used, the results of which have been presented in Table (5).

Table 5. T-test of independent samples in control and experimental groups

Group	Number	Statistical indicators of t-test		
Control	25	t	Degree of freedom	The significance level of P
Experimental	25	6.926	48	0

As shown in Table (5), the null hypothesis (the means of the two groups are not different) was rejected, thus the opposite assumption (the means of the two groups are different) was accepted. As a result, teaching to eliminate "equation solving" misconception was effective on students' misconception scores, and it can be concluded that teaching to eliminate misconception reduced “equation solving” misconceptions. In other words, in response to the question of whether identifying students’ misconceptions affects students’ problem-solving skills, according to the results obtained from statistical analysis, it can be said that the identification of misconceptions affected the improvement and promotion of students' equation solving skill. According to Table (5) and the results obtained in response to the second question of the research, it can be confirmed that Bruner’s method was effective in reducing the misconceptions of equation solving.

Also, the results of the covariance analysis test confirmed the effect of teaching based on Brunner's theory on the reduction and elimination of misconception. The reason for using covariance analysis was that factors such as prior learning and so on may influence the scores of the dependent variable. Thus, in order to adjust for group differences, the pretest scores of maladaptation as co-variables were used to adjust the effect of initial differences on the scores of the dependent variable.

Prior to performing the covariance analysis, some assumptions are required. The three main assumptions of covariance analysis are (i) normality of data on spatial variables (post-test and pre-test), (ii) homoscedasticity, and (iii) homogeneity of regression lines. These basic assumptions for the learning variable have been discussed below.

As shown in Table (6), the magnitude of these statistics was not significant for the post-test and pre-test scores (misconception), which means that the data assumption was normal. In other words, the distribution of scores was normal.

Table 6. Kolmogorov-Smirnov test for checking the normality of pre- and post-test regarding misconception data.

Type of test		Misconception pre-test	Misconception post-test
Number		50	50
Normal parameters	Mean	17.42	9.560
	SD	3.225	2.914

Extreme differences	Absolute	0.237	0.116
	Positive	0.110	0.116
	Negative	-0.237	-0.089
Kolmogorov Smirnov Z		1.676	0.821
The significance level of the two domains		0.07	0.510

As shown in Table 7, the obtained significance level (0.557) was greater than 0.05, thus the assumption of homoscedasticity was confirmed.

Table 7: Leven test to examine the assumption of homoscedasticity

F	1 degree of freedom	2 degree of freedom	Significance level
0.314	48	1	0.578

According to Table (7), the obtained significance level (0.634) was more than 0.05. Therefore, the assumption of homogeneity of the regression lines was confirmed.

Table 8. Assumption of homogeneity of regression lines of misconception test

Source of variance	Sum of squares	Degrees of freedom	Mean square	F	Significance level
Corrected model	212.703	3	70.901	16.018	0.000
y-intercept	90.858	1	90.858	20.526	0.000
group	2.171	1	2.171	0.491	0.487
Pre-test learning	4.243	1	4.243	0.958	0.333
Group * pre-test learning	1.017	1	1.017	0.230	0.634
Error	203.617	46	4.426		
Total	4986.000	50			
Corrected total	416.320	49			

Given that all three assumptions of covariance analysis were confirmed, the use of covariance was permissible.

Table 9. Covariance analysis test for comparing the scores of teaching groups in the misconception test

Source of variance	Sum of squares	Degrees of freedom	Mean square	F	Significance level	Eta squared
Corrected model	211.686	2	105.843	24.310	0.000	0.508
y-intercept	98.280	1	98.280	22.573	0.000	0.324
Misconception ore-test	3.606	1	3.606	0.828	0.367	0.017
group	280.080	1	280.080	47.791	0.000	0.504
Error	204.634	47	4.354			
Total	4986.000	50				
Corrected total	416.320	49				

According to the results of the table ($p < 0.05$, df = 1, F = 47.791), it is shown that when the pre-test`s effect was moderated by the learning outcomes, the difference between the traditional and the pattern of education based on Bruner's theory was significant at 95% significance level. Therefore, there was a significant difference between the scores of the groups in the learning test and the null hypothesis of the research was rejected.

Conclusion

First question: Does teaching with the help of Bruner's theory reduce and eliminate students` misconceptions?

Based on the results of data analysis such as independent t-test as well as the analysis of the results of the covariance test between the control and pre-test and post-test groups, it was found that there was a significant difference between traditional education and Brunner's theory. It can be concluded that teaching based on the Bruner method was effective in reducing and eliminating students' misconceptions in solving equations and accordingly, such misconceptions could be prevented.

Second question: Is teaching with the help of Bruner's theory effective in improving students' equation solving skills?

As explained in the preceding question, teaching and training based on Bruner's theory could be effective in reducing and eliminating misconceptions. Consequently, it can be concluded that by reducing misconceptions, the equation solving skills could increase, meaning that there was a reverse relationship between the reduction and elimination of misconceptions and the equation solving skill. By reducing and preventing misconceptions, students' equation solving skills were improved, however, increasing misconceptions was effective in reducing their equation solving skills.

Misconceptions can be caused by inappropriate training, informal thinking, or poor memory [3]. Stacey and McGregor (1997) stated that the roots of misconceptions and errors often lie in the instructional styles of teachers and the materials they choose to teach. According to the discussed topics, misconceptions can be considered as the students' effort to achieve a good understanding, and this may give rise to other misconceptions. With regard to the identified misconceptions, the most important step to prevent them is to identify these misconceptions. Understanding the causes of these misconceptions will help researchers adopt an effective strategy to prevent them and it should be clear why these types of misconceptions occur. In this study, the identification of students' misconceptions in equation solving showed that most students still had difficulty in understanding the basic concepts of algebra and equation issues which formed the context for other misconceptions, so that the persistence of these mistakes and misconceptions is very high and sometimes irreparable.

Welder (2010) believed that it would be difficult to correct students' conceptual errors, even for the best algebra teachers, because they have been internalized over the years of previous mathematics education. Thus, instead of focusing on correcting existing conceptual errors, it is better for teachers to prevent them from forming.

In understanding misconceptions and their causes, one should consider the relationship with students' backgrounds. For example, one of these basic and prerequisite concepts in equation solving and other algebraic concepts are the variables that well-known misconceptions of the equation are related to. Therefore, it is necessary to adequately explain the importance of the variable concept and justify its role as a number for students. It should also be clear to them that the variable can be represented by any letter, not just by the letter “x”. Variable roles in patterns, sequences, numerical values, and problem-solving can be illustrated for students by citing examples and in various modes. Then we need to show the variable`s relationship with the equation and solve it. Other causes of misconceptions in equation solving that play an important role as a variable may include equality symbols, especially in its operational and relational understanding. Moreover, students' lack of familiarity with equality symbol features can be effective in increasing these misconceptions.

However, to use Bruner's theory in education, major obstacles such as classroom population density, allocated time, and the required tools should be considered. Since using such a theory can make students critical, active, questioning, curious and most importantly responsible, so that they can directly manage their own learning and replace exploratory learning with parrot learning.

Therefore, it is better to spend more patience in the training of algebra and the equation and to consider the effective and hidden external factors and their role in causing misconceptions and not to use a variable in repeated examples. Using a variety of attractive and practical problems, especially the role of equations in solving real-world problems, can provide attractive students with additional motivation. A variety of examples should be used along with misconceptions. One thing to keep in mind is the verification of the answer to any equation that can be verified by replacing the equation correctly and the second issue is paying attention to the causes of account misconceptions and their relation to algebraic misconceptions. Moreover, the role of negative numbers and fractions in the equation misconception should not be neglected.

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