INTERNATIONAL JOURNAL OF ACADEMIC RESEARCH IN PROGRESSIVE EDUCATION & DEVELOPMENT
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ISSN: 2226-6348

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Yasseen AL-Rababaha, Wun Thiam Yew, Chew Cheng Meng

To Link this Article: http://dx.doi.org/10.6007/IJARPED/v11-i1/12197 DOI:10.6007/IJARPED/v11-i1/12197

Received: *09 November 2021,* ***Revised:*** *12 December 2021,* ***Accepted:*** *30 December 2021*

Published Online: 23 *January 2022*

In-Text Citation: (AL-Rababaha et al., 2022)

To Cite this Article: AL-Rababaha, Y., Yew, W. T., & Meng, C. C. (2022). Algebra Misconceptions among Tenth Graders in the United Arab Emirates. *International Journal of Academic Research in Progressive Education and Development*, *11*(1), 713–728.

Vol. 11(1) 2022, Pg. 713 - 728

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ISSN: 2226-6348

Algebra Misconceptions among Tenth Graders in the United Arab Emirates

Yasseen AL-Rababaha
University Sains Malaysia- Malaysia
Email: alrababahyasseen@gmail.com

(Co-authors) Dr. Wun Thiam Yew, Dr. Chew Cheng Meng
University Sains Malaysia- Malaysia
Email: tywun@usm.my, cmchew@usm.my

Abstract
This paper aims to highlight on the students' misconceptions for Tenth Graders in algebra in the United Arab Emirates. The authors explain the importance of algebraic concepts in understanding algebra and other branches of mathematics as well as other related topics. The authors explain how algebraic conceptual errors impair students' performance in mathematics. The authors provided the expected sources of students' conceptual errors. Based on the Algebra Test (AT) and the Face to Face Interview Protocol (FFIP), the authors presented the common algebraic misconceptions that Tenth Graders have in the United Arab Emirates. It was emphasized that conceptual errors must be detected in school algebra and research should be expand to find effective instructional strategies to minimize these felled algebraic misconceptions.
Keyword: Algebra, Algebra Misconceptions.

Introduction

Students in school mathematics develop their concepts using their teachers, peers, day experiments and teaching environment. In case that a student develops a concept inaccurately in his/her mind, he or she may have a misconception (Kaya, Karadeniz, & Bozkus, 2017). Ojose (2015) defined misconception as misinterpretation and misunderstanding based on incorrect meanings. It is common knowledge that misconceptions students have in algebra and other branches of mathematics weaken their abilities in constructing accurate mathematics concepts.

As a core branch of mathematics, a sound understanding of algebraic concepts enhances students’ performance in understanding algebra and other branches of mathematics such as geometry and probability. Consequently, algebraic misconceptions inhibit students’ understanding of algebra and have negative influence on understanding other related branches of mathematics. Students with algebraic misconceptions may face difficulties in solving problems in other related subjects like physics, chemistry and economics.

In the United Arab Emirates, tenth graders move to the secondary schools carrying with them a mix of correct and incorrect algebraic concepts that they acquired during pre-secondary schools. In this country, the algebra curriculum consists of system of linear equations, quadratic functions and equations, polynomials and polynomials functions: operations with polynomials and inverse and radical functions. As a mathematics teacher for this grade for five years, one of the authors observed that students face difficulties when they try to solve algebraic problems using their preconceptions. He noticed that students' previous misunderstandings affect students' performance in algebra and other related topics. In this paper, the authors attempt to highlight the conceptual errors in algebra among tenth grade students in the United Arab Emirates, classifying these preconceptions and identify thinking strategies related to these misconceptions. It should be understandable to colleagues from a broad range of scientific disciplines.

In literature, authors focus on variety of common algebraic misconceptions in different levels of school algebra including algebraic expressions, linear equations, polynomials, exponents, radical expressions, and functions and graphs. Some past studies were conducted to determine undergraduate students' misunderstandings in calculus. In this section, some literature will be reviewed for tenth graders algebraic misconceptions other related school algebra misunderstandings.

For algebraic expression misconceptions, Chow and Treagust (2013) observed that students simplified $3x + 4$ as $7x$. They see the (+) symbol as invitations to do something. Students assume that the answer should not contain an operator symbol. The same result found by Irawati and Ali (Irawati & Ali, 2018) when students treated algebraic expressions with two variables. They simplified $3x + 4y$ as $7xy$. Luka (2013) named this misconception as an over simplification. He noticed that students wrote "2 or $2x$" when they asked to subtract $3x$ from 5, While others answered with reversal error and wrote $3x - 5$. Seng (2010) found that students simplified $-6x + 3x$ as $-9x$. They add the terms without considering negative sign. Then, they write negative sign back in their solution. For the item like $p - 2c + p - 5p$, students fails to collect positive and negative terms. They simplified the expression as $7p - 2c$ (Ndemo, O. & Ndemo, Z., 2018). Also, they observed that students simplified $x(\frac{a}{b})$ as $\frac{ax}{bx}$. They described this misconception as a "multiplication of algebraic expressions confused with indices". Saputro, Suryadi, Rosjanuardi and Kartasasmita (2018) noticed that some students add algebraic fractions incorrectly. They wrote $\frac{3x}{8} + \frac{x}{4} + \frac{x}{2}$ as $\frac{3x^3}{14}$.

Fui and Lian (2018) observed that students omit to use distributive property. For example, for 3(a + 7), students add x with 7 to get $7x$ and then multiply the answer with 3 to get $21a$: $3(a + 7) = 3(7a) = 21a$. They also found a negative sign misconception. Students interpret $-(6x + 3y)$ as $-6x + 3y$. Egodawatte (2011) observed that students mistakenly distributed exponentiation over addition as $(x + y)^2$ as $x^2 + y^2$.

For linear equation misconceptions, Ngoveni and Mofolo-Mbokane (2019) found that students added unlike terms inside the brackets when try to solve the equation $y\,(2y + 1) = 15$. They wrote: $2y + 1 = 3y$. Then they multiplied 15 (on the right side of the equation) with $3y$ to get 45 as a final answer. Toka and Askar (2002) found that some students rewrote the equation $5 - 3\,(2 - x) = -7$ as $5 - 6 - 3x = -7$. They used the distributive property incorrectly. Others wrote the same equation as $2(2 - x) = -7$. They used the order of operations inaccurately. The researchers indicated that students believed that negative signs do not modify terms. Dodzo (2016) found that some students rewrote the equation $2a - 5 = 10 - ax$ as $2a - 5 - 5 = 10 - 3a$, and then $2a = 10 - 3a$. They named this misconception as an "omission error". Also, some students rewrote the equation $1 - 2a = 13$ as $1 - 13 = 2a$ and then, $12 = 2a$. They the "inverse error" misconception. Li (2006) noticed that some students treat the equation $10 = 3 + 5x$ as $10 = 3 + 5 + x$. They omitted sign "×" as "+". To solve the linear equation like $-3x + 6 = 2x + 16$, students subtract $2x$ from the both sides:

$-3x + 6 = 2x + 16$
$\quad -2x \qquad -2x$

to get $x + 6 = 16$. They omitted the negative sign (Aydin-Guc, F. & Aygun, D., 2021). Some students do not change the sign when they move an item from one side to another (Booth, Barbieri, Eyer, & Blagoev, 2014). Fore example, moved $5x$ in the equation $2 + 5x = 1 - 3x$ to the right side without changing (+) sign to (-) sign.

For Radical Expressions misconceptions, Mulungye (2016) found that some students interpret $\sqrt{a^2 + b^2}$ =$a + b$. The same misconception was found by A'yun and Lukito (2018) Students worked $\sqrt{x^2 + y^2}$ as $x + y$. For functions and their graphs misconceptions, Öçal (2017) observed that students roughly sketched functions of $\frac{1}{x}$, $\ln x$ and e^x . They had the asymptote misconception. Also students did not give explanations about their sketches. Bush (2017) found some misconceptions related to interpreting a given function graph. They estimated wrongly a value of $f(x)$ for a given x. Also, they expected inaccurately a value of a linear function that was outside the area shown in the graph.

Methods

Design

The purpose of this paper is to determine the common conceptual errors that Grade Ten students have with algebra in the United Arab Emirates. Both quantitative and qualitative methods were used in order to acquire target information. The authors administrated Algebra Test (AT) and designed Face to Face Interview Protocol (FFIP) to identify and classify common misconceptions in algebra. Reviewing the literature regarding the misconceptions in algebra for this stage of school mathematics would be useful to develop the test of algebraic target preconceptions and design the interview.

Participants

The population of the study consisted of all Grade Ten male students in public schools of ALAIN city in the United Arab Emirates for the academic year 2019/2020. Precisely, target population was 20 classes of 543 Grade Ten male students. Simple random sampling was conducted to choose (4) classes of Tenth Graders from two schools (a total of 117 students). For the purpose of identifying common misconceptions that students have in algebra, the researcher selected 18 students from the four classes mentioned above to be interviewed.

Instruments

(1) Algebra Test (AT)

The Algebra Test (AT) instrument was used to identify conceptual errors in algebra for Tenth Graders. The AT items were devolved by using literature, the mathematics syllabus for Grade Ten and one the authors as a mathematics teacher in a secondary school in Al-Ain, the city where the study was conducted. As a classification of expected misconceptions, the test consisted of four groups of items:

(a) Algebraic Expressions: For this category, the AT consisted of five items about simplifying algebraic expressions, letter usage and expanding algebraic expressions, which were as follows:

Simplify where possible:

(1) $3x + 4$, the expected misconception is the inability to simplify an expression correctly because the misunderstanding of the concept of like terms. The expected incorrect answer is $7x$.

(2) $2x + 3y$, the expected misconception is the inability of understanding variables as varying quantities rather than a missing value. The expected inaccurate answer is $5xy$. (3) $6a^2 + 3a - a$, the expected misconception is the inability to simplify an expression accurately because the misunderstanding of the concept of like terms. The expected incorrect answer is $8a^2$. (4) $5y + 3(y - 4)$, the expected misconception is the incorrectly simplifying because of not using distributive property correctly. The expected incorrect answer is $8y - 4$.

(5) $\frac{5x}{2} + \frac{2x}{6}$, the expected misconception is the inability to add algebraic fractions correctly, students add numerators and denominators instead of rewriting each fraction with a common denominator. The expected inaccurate answer is $\frac{7x}{8}$.

(b) Linear Equations: For this category, the AT consisted of five items about solving linear equations. The items were as follows:

Solve each equation:

(6) $3(a - 2) + 5 = 4$, the expected misconceptions are relating to (1) incorrect simplification of distributive property and (2) error in using inverse operations. The expected inaccurate answer is as follows:

$$3a - 2 + 5 = 4$$
$$4a + 3 = 4$$
$$4a = 7$$

(7) $x = \frac{7}{4} - \frac{y}{4} = 3$, the expected misconception relates is that students incorrectly write an expression such as x instead of $-\ x$. The expected incorrect answer is as follows:

$$-\frac{x}{4}.\ 4 = 3$$
$$x = 12$$

(8) $\frac{x-2}{5} = 3$, the expected misconception relates to errors in using inverse operations. The expected inaccurate answer is as follows:

$$\frac{x-2}{5} + 2 = 3 + 2$$
$$\frac{x}{5}\,.5 = 5\,.5$$
$$x = 25$$

(9) $9x - 5 = 3x + 1$, the expected misconception relates to errors in using inverse operations. The expected inaccurate answer is as follows:

$$12x = 6$$
$$x = 2$$

(10) Find the possible value(s) of $a\ and\ b$ that makes this equation true $a + b = 12$? The expected misconception relates to that some students treat the letters x and y as they might

treat empty boxes. They might write that each of a and b has exactly one value: $a = 5, b = 7$ or $a = 4, b = 8$ or $a = a, b = 6$.

(c) Polynomials, Exponents and Radical Expressions: For this category, the AT consisted of five items about polynomials, simplifying radical expressions and exponents operations. The items were as follows:

Simplify where possible:

(11) $(3y + 2)(2y - 5)$, the expected misconception relates to incorrectly multiplying polynomials because of not using distributive property accurately. The expected incorrect answer is $6y^2 - 10$.

(12) $(x + y)^2$, the expected misconception relates to inability to understand exponents laws and incorrectly multiplying polynomials because of misunderstanding of using distributive property correctly. The expected incorrect answer is x^2y^2.

(13) $\sqrt{x + y}$, the expected misconception relates to incorrect simplification of radical expressions. The expected incorrect answer is $\sqrt{x} + \sqrt{y}$.

(14) $e^a e^b$, the expected misconception relates to inability to understand exponents properties. The expected incorrect answer is e^{ab}.

(15) $(m^2n^5)^3$, the expected misconception relates to inability to understand exponents properties. The expected incorrect answer is m^5n^8.

(d) Functions and Graphs: For this category, the AT consists of five items about linear functions and their graphs.

The items were as follows:

(16) If $f(x) = 3x - 2$, find the value of $f(2)$, the expected misconception is to inability to find value of the function $f(x)$ for a given x correctly. The expected incorrect answer is

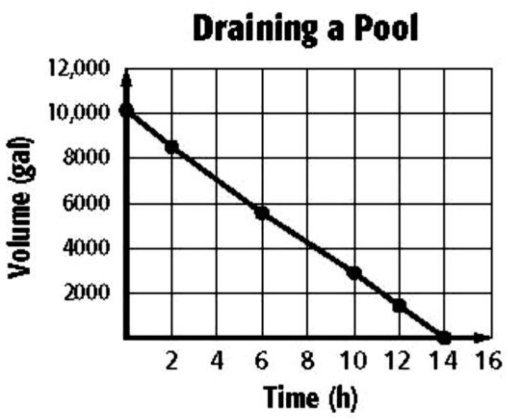
$$f(2) = 32 - 2$$
$$= 30$$

(17) A teacher claimed that the relationship between numbers of hours studied for a test and a test score can be described by $f(x) = 7 + 3x$, where x represents the number of hours studied. Ahmad score was 10. How many hours did he study?

The expected misconception is to inability to understand of independent and dependent variable. The expected incorrect answer is as follows:

$$f(10) = 7 + 3(10)$$
$$= 37$$

For the graph of a linear function below, answer the following questions:



(18) State the independent and independent variables. The expected misconception is inability to identify independent and dependent variables for a linear function graph. The expected incorrect answer is: volume is the independent variable and time is the dependent variable.
(19) Describe what the y-intercept means. The expected misconceptions are (1) inability to identify y-intercept correctly and (2) inability to explain what the y-intercept means.
(20) Estimate the time in which the pool contains 6000 L. The expected misconception is inability to estimate the value of x- coordinate for a given value of y coordinate for a graphed linear function.

(2) Face to Face Interview Protocol (FFIP)

The FFIP was used to detect other misconceptions in algebra for Tenth Graders or to interpret those conceptual errors that were appeared in student's responses to the AT. The strategies that were associated with these misconceptions was observed. This semi-structured interview included a set of questions which last for 30 to 40 minutes.

Each interviewee was asked about all misconceptions that he had in the AT. The authors developed the FFIP questions based on the items of the AT. The interviewees were asked to write down their answers using a pencil and paper. Here is a sample of interview questions:
Can you write down your answer for the first question of the AT?
Why? Explain your justification of the answer?
Have you encountered any difficulty through answering this question? If yes, explain these difficulties?
Your answer for question two was (incorrect answer). Can you explain the reason why you chose this answer?
To make sure if the interviewee sticks of his misconception, the interviewee was asked to compare his answer (inaccurate answer) with the correct answer given by one of his peers:
One of your peers responded to the third question as follows: " $6y^2 + 2y$ ". What do you think of his answer? Is his answer correct? Explain why.
For the purpose of determining the specific misconception in a problem, the interviewee was asked about the procedures that he followed to get the answer:
For question four, write down all the steps that you followed to find the answer?
The previous interview elements were repeated in whole or in part for the other groups of questions that were included in the test.

Data Analysis

The authors used students' responses to the AT items and FFIP questions to identify and classify students' misconceptions in algebra. In case of other types of misconceptions that could appear in students' responses, the authors highlighted and categorized these conceptual errors.

Results and Discussion

The results of this study show that all students had a variety of algebraic misconceptions in varying degrees. The authors observed that the difficulties in algebra for the students ranged between computational errors and the absence of the concept completely. The study showed that many misconceptions for participants were similar to the conceptual errors of their counterparts in other research in different countries (Akhtar &

Steinle, 2013;Mulungye, O'Conner, & Ndethiu, 2016; Muzangaw & Chifamba, 2012). The results are categorized into four subsections as follows:

(1) Algebraic Expressions Misconceptions

The AT results showed the following algebraic expressions misconceptions which were
as follows:

The most common misconception in this category was adding algebraic fractions inaccurately. 84% of students simplified the expression $\frac{5x}{2} + \frac{2x}{6}$ incorrectly. 58% of them simplified $\frac{5x}{2} + \frac{2x}{6}$ as $\frac{7x}{8}$ by adding numerators and denominators separately. The remaining 26% of the students treated the same expression as a rational equation. They used cross multiplication and rewrote $\frac{5x}{2} + \frac{2x}{6}$ as $5x \times 6 = 2x \times 2$.

The using of distribution property incorrectly was the second most common algebraic expressions misconception. 83% of them simplify $5a - 3(a - 4)$ as $5a^2 - 3a - 12$, rewrote the same expression as $5a - 3a - 12$ or wrote $5a^2 - 3a - 20 - 12$ as a simplest form of the expression $5a - 3(a - 4)$.

The third most common algebraic expressions misconception appeared when 62% of the participants treated $3x + 4$ as a linear equation. 51% of them rewrote $3x + 4$ as $3x = -4$ and then $x = \frac{-4}{3}$ while 11% of them wrote $2x + 3y$ as $2x = 3y$.

It was found that around 40% of participants simplified $6y^2 + 3y - y$ as $8y^2$, $9y^2$ or $8y^4$. This misconception was the fourth most common algebraic expressions misconception in this category. For the fifth most common algebraic expressions misconception, students were merged the algebraic addition and subtraction incorrectly. 23% of the participants simplified $3x + 4$ as $7x$ or $2x + 3y$ as $5xy$. Figure 1 shows sample of student's algebraic expressions misconceptions that were found in this study.

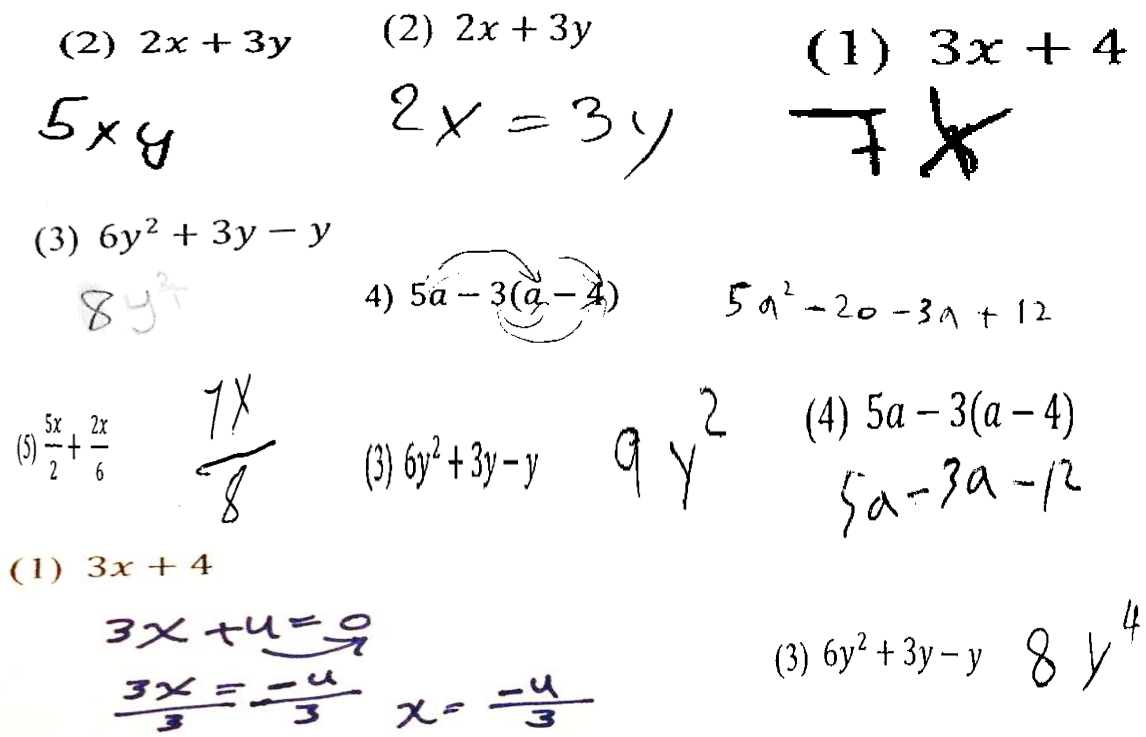


Figure 1. Sample of student's algebraic expressions misconceptions that were found in this study.

In order to identify further conceptual errors or to interpret those misconceptions that were performed in student's responses to the AT, 18 students were interviewed. During the FFIP, interviewees showed that they defended their previous concepts and were stuck with their algebraic misconceptions. For example, student (HS) used the distributive property inaccurately when he simplified $5a - 3(a - 4)$.

Author (A): Write down your answer for the item (4) Simplify the expression $5a - 3(a - 4)$?
HS: $5a - 3a - 12$
A: Have you met any difficulty through answering this question?
HS: No.
A: Can you clarify your answer?
HS: I multiply "-3" with "a" and "4" to get $5a - 3a - 12$.
The student omitted the negative sign.
A: Why did you choose this answer?
HS: In this kind of problems, I have to use distribution property.
Student (HM) treated the expression $3x + 4$ as an equation.
Author (A): Write down your answer for the item (1) Simplify the expression $3x + 4$?
HM: $\frac{3x}{3} + \frac{4}{3} \quad x = \frac{-4}{3}$
A: Have you encountered any difficulty through answering this question?
HM: yes.
A: Can you explain your answer?
HM: I moved the number "4 to the right side, and then divided the both sides by 3 to get $\frac{-4}{3}$ as a final answer.
A: Why did you choose this answer?
HM: I treated it as an equation.
The student (ME) believed that he can add numerators and denominators separately when he simplify $\frac{5x}{2} + \frac{2x}{6}$.
A: Write down your answer for the item (5) Simplify the expression $\frac{5x}{2} + \frac{2x}{6}$?
ME: $\frac{7x}{8}$.
A: Have you encountered any difficulty through answering this question?
ME: No.
A: Can you explain your answer?
ME: $5x + 2x = 7x$ and $2 + 6 = 8$.
A: Why did you choose this answer?
ME: I substitute "1" in both side. They were equal.
It is clear that the student (ME) also add numerators and denominators separately to adding fractions and algebraic fraction. He explained that he calculated $\frac{5(1)}{2} + \frac{2(1)}{6} = \frac{7}{8}$ and $\frac{7(1)}{8} = \frac{7}{8}$, he decided that.
For the item (1): simplify $3x + 4$, student AR wrote "$7x$" as a simplest form.
A: Can you explain your answer?
AR: I add "3" and "4" to get "7". We can ignore "x" in this case.
A: Why?

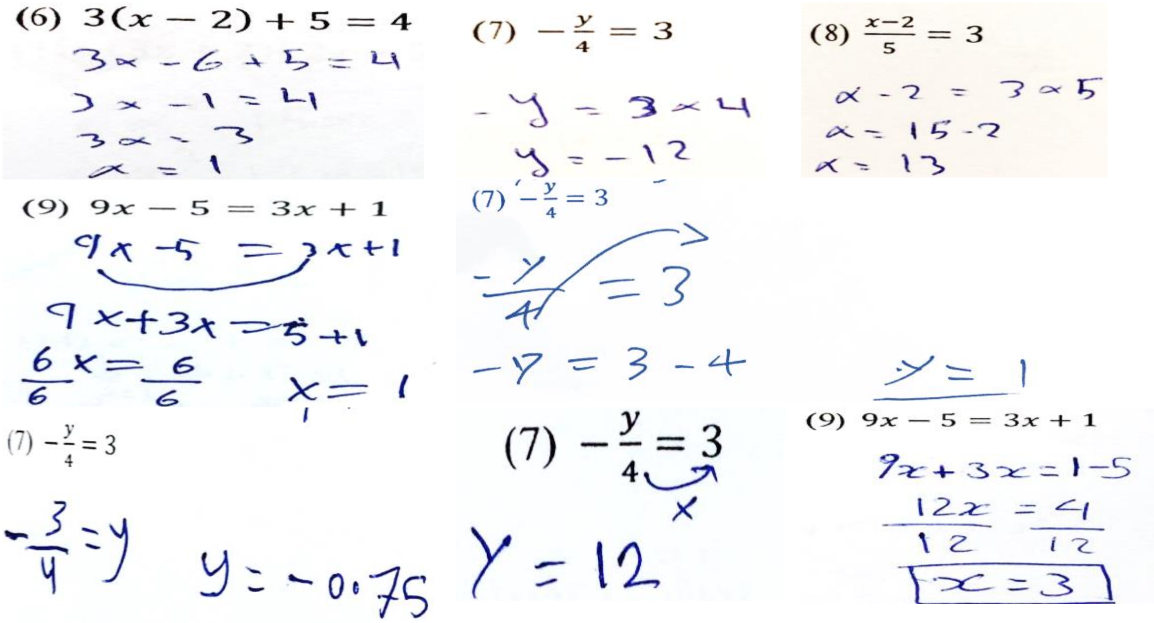
AR: "x" is not needed.
Student AS simplified $6y^2 + 3y - y$ as $8y^4$.
R: Can you explain your answer?
AR: I added the powers and calculated the coefficients.
R: Why did you choose this answer?
AR: we simplify expressions in this form ($6y^2 + 3y - y$) by adding the powers of all terms (2 + 1 + 1 = 4) and calculate the coefficients of all terms (6 + 3 – 1 = 8) to get $8y^4$.

(2) Linear Equations Misconceptions

The AT results showed four common linear equations misconceptions which were as follows:
The participants had several misconceptions related to solving linear equations. Around 95% of the participants treated the letters x and y as they might treat empty boxes. They considered that each of x and y has exactly one value: $x = 5,\ y = 7\ or\ x = 4,\ y = 8\ or\ x = 6, y = 6$.They explained that the equation has finite number of solutions which was the most common linear equations misconception.

56% of the participants used inverse operation incorrectly which was the second most common linear equations conceptual errors. 29% of the them used division as an inverse operation instead of multiplication when they solving the equation:$\frac{-y}{4} = 3$. They divided the both sides of the equation by "-4 "to get $y = -\frac{3}{4}$ as a solution of the equation. The remaining 27% of the students incorrectly rewrote the equation $9x - 5 = 3x + 1$ as $9x + 3x = 5 + 1$.

The third most common linear equations misconception was omitting the negative sign incorrectly. 48% of students omitted the negative sign when they solved the equation $\frac{-y}{4} = 3$. They multiply both sides by "3" and get $y = 12$. 33% of the students used distributive property incorrectly and expanded $3(x - 2)$ as $3x - 2$ or $3x + 6$ when they asked to solve the equation $3(x - 2) + 5 = 4$. This was the fourth most common linear equations misconception. Figure 2 shows sample of student's linear equations misconceptions that were found in this study.



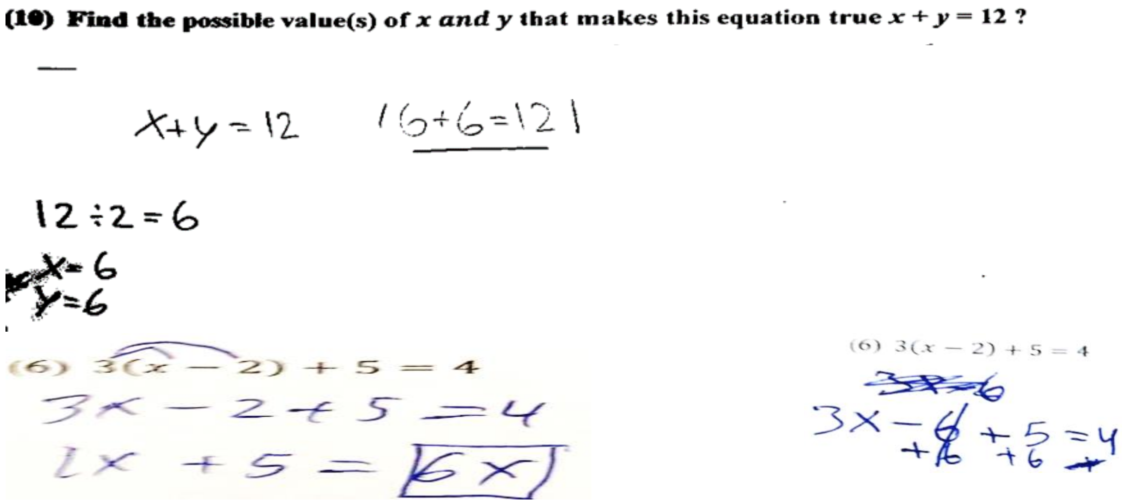


Figure 2. Sample of student's linear equations misconceptions that were found in this study.

During the FFIP the author asked each interviewee a group of questions to get some clarifications about participants' linear equations misconceptions. Interviewees presented different explanations that confirmed the existence of students misunderstanding about linear equations. For example, student (SO) wrote $y = \frac{3}{4}$ as solution of the equation $\frac{-y}{4} = 3$.

A: Can you explain your answer?
SO: I divided both sides of equation by 4 and omitted the negative sign because the number "4" moved to the right side.
The student uses the inverse operation incorrectly and omitted the negative sign wrongly.
For the item (10) Find the possible value(s) of x and y that makes this equation true $x + y$ = 12? Student (MA) wrote: $x = 6, y = 6$.
A: Is there any other solution?
MA: No, this equation has only one solution.
A: What about $x = 7, y = 5$?
MA: That is wrong, x and y must be equal.
The researcher asked student (HS) to write his answer for the item (8): solve the equation $\frac{x-2}{5} = 3$? He wrote: $x - 2 = 15$. He chose the first inverse operation correctly by multiply both sides by 5.
A: Write down the second step?
HS: $x - 2 = 15$ and then, $x = 13$.
A: How?
HS: I subtracted the number "2" from both sides of the equation.
The student chose the second inverse operation incorrectly.

(3) Polynomials, Exponents and Radical Expressions Misconceptions

The AT results showed five of polynomials, exponents and radical expressions misconceptions which were as follows:

The most common misconception in this category was the exponent misconception. 96% of the participants simplified the expression $e^{a}.x^{a}$+ $e^{a}.y^{b}$ as $e^{ab}x^{ab}$ or $e^{a^2}x^{b^2}$ as the simplest form.

In the second place, a misconception related to simplifying radical expression like $\sqrt{a+b}$ was occurred. 95% of the participants rewrote it as $\sqrt{a} + \sqrt{b}$.

The third most common misconception in this category occurred when 88% of the participants were expanding $(a+b)^2$ as $a^2 + b^2$. They usually distributed the power "2" to the both terms "a" and "b".

The fourth most common misconception in this category occurred when students were asked to simplify the item ($3x$ + 2) ($2x$ − 5). 69% of the students wrote $3x.2x$ as $6x$ or expanded ($3x$ + 2) ($2x$ − 5) as $6x^2 - 10$.

53% of the participants wrote m^5p^8 as a simplest form instead of m^6p^{15} which was the least common misconception in this category. Table 4.3 shows the percentages of the most common polynomials, exponent and radical misconceptions. Figure 3 shows sample of student's polynomials, exponent and radical misconceptions that were found in this study.

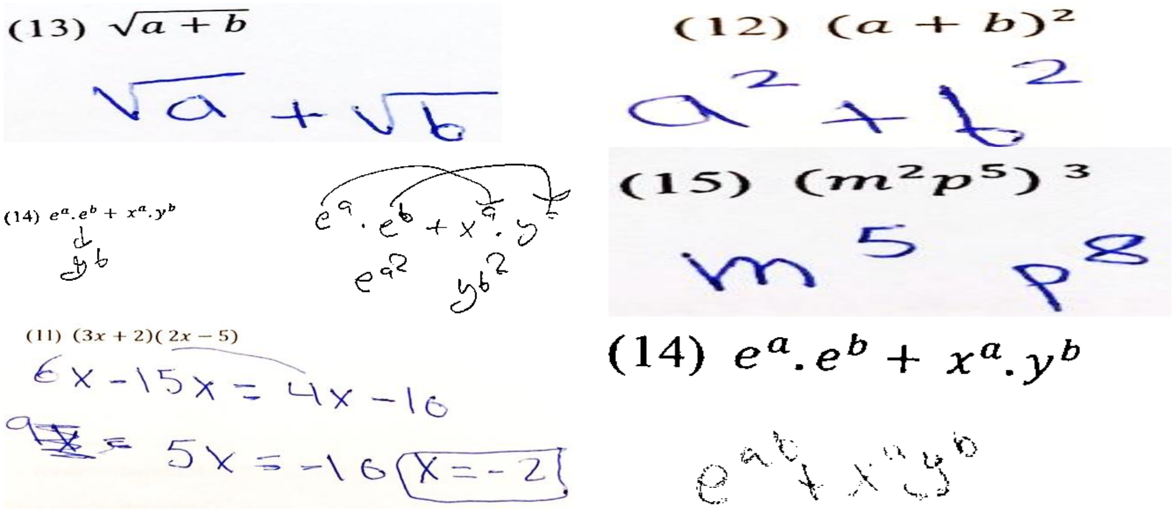


Figure 3. Sample of student's linear equations misconceptions that were found in this study.

During the FFIP, for polynomials, exponents and radical expressions misconceptions category, the author presented the item (13): Simplify $\sqrt{a+b}$? to the student ME.

A: Your partner's answer for this item was $\sqrt{a+b}$, what is your opinion?

ME: No, his answer is wrong.

A: Why?

ME: The square root must be removed.

The student thought wrongly that a radical expression must be simplified by eliminating the root. Also, student (SA) confirmed that $(a+b)^2 = a^2 + b^2$. He indicated that this expression can be simplified by distributing the power "2" to the terms "a" and "b".

A: Can you explain why you thought that this process is done like this?

ME: Both terms must be squared, that is it.

For the item (11): Simplify $(3x+2)(\ 2x-5)$?, student (AM) wrote $11x$ as the simplest form.

A: Write down all steps that you followed to reach the answer?

ME: I used distributive property by multiplying the terms "$3x$" and "-5", "2" and "$2x$" separately. I got "$-15x$" and " $4x$" and then, I combined these two terms as they are alike to get "$11x$" finally.

For the item (14) Simplify $e^a . e^b + x^a . y^b$, student (MH) argued that $e^{2ab} + x . y^{ab}$ is the simplest form of the expression.

A: Can you explain your answer?

MH: $e . e = e^2$, $a . b = ab$, $x . y = xy$ and $a . b = ab$. Thus, $e^a . e^b + x^a . y^b$ = $e^{2ab} + x . y^{ab}$.

A: Why did you choose this answer?

MH: Because $e . e = e^2$ and $x . y = xy$.

The student multiplied the base and the powers separately in the first term instead of adding powers. Also, he multiplied the powers and ignored the power of "x". He tried to simplify the second term although it is in simplest form. The student misinterpreted the rules of index.

(4) Functions and Graphs Misconceptions

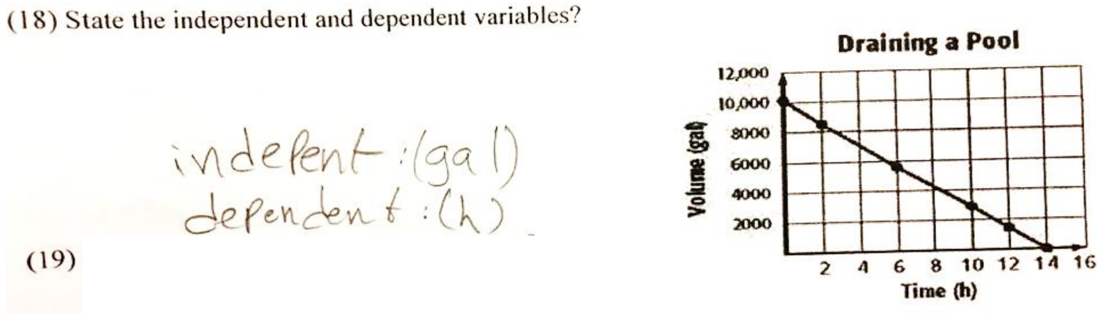
The AT results showed four of functions and graphs misconceptions which were as follows:

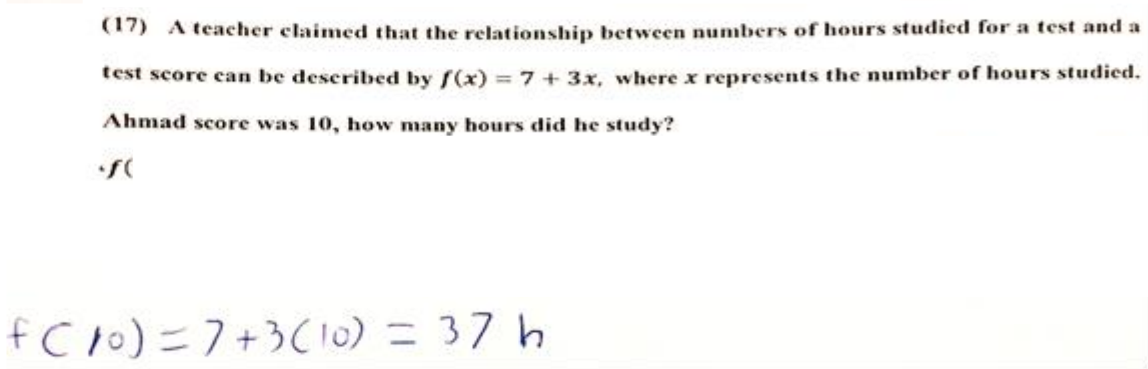
89% of learners didn't distinguish between independent and dependent variables using given linear function graph. This misconception was the most common misconception in this category. The second most common misconception in this category was confusing with the meaning of "dependent variable" which represented "mark" in that item. 79% of the students substituted the value "10" as a value of "x: the number of hours studied" instead of "y: test score" in the following item:

"A teacher claimed that the relationship between numbers of hours studied for a test and a test score can be described by $f(x) = 7 + 3x$, where x represents the number of hours studied. Ahmad score was 10, how many hours did he study?"

In the third place, 76% of students didn't recognize the accurate meaning of the concept "y-intercept" on a given graph and/or they couldn't describe what a given value of "y-intercept" represents.

The fourth most misconception in this category occurred when 70% of students treated incorrectly $f(3) - f(1)$ as $f(2)$ for a given linear function. Figure 4 shows sample of student's linear functions and their graphs misconceptions that were found in this study.





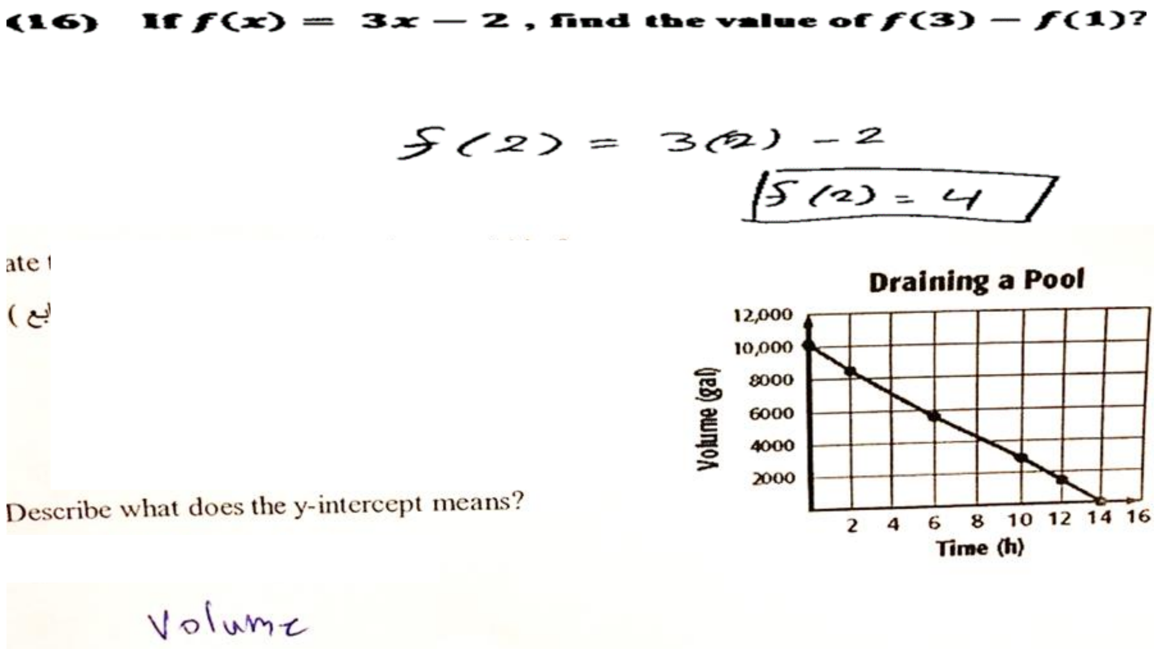
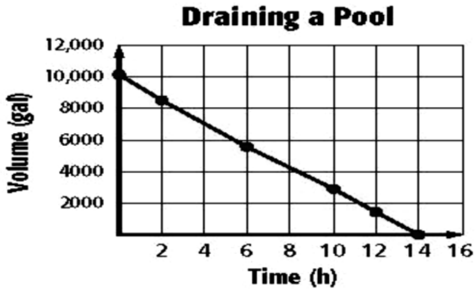


Figure 4. Sample of student's linear functions and their graphs misconceptions that were found in this study.

During the FFIP, the researcher found some conceptual errors related to functions and graphs. For example, student (MH) found $f(3) - f(1)$ as $f(2)$.
A: Can you tell me how you answered this question?
MH: $f(2) = 3(2) - 2$.
A: Write down all steps that you followed to reach the answer?
MH: To find $f(3) - f(1)$, I wrote $3 - 1 = 2$, then I substituted "2" in the function $f(x) = 3x - 2$. I wrote $f(2) = 3(2) - 2$.
The student knew how to find the value of a function at a certain number but he misunderstands finding the difference of two values of a function at two certain numbers.
The student (KR) didn't distinguish between independent and dependent variables for a function.
A: For the item (17): A teacher claimed that the relationship between numbers of hours studied for a test and a test score can be described by $f(x) = 7 + 3x$, where x represents the number of hours studied. Ahmad score was 10, how many hours did he study? Can you tell me how you answered this question?
MH: I substituted "10" in the function.
A: Write down all steps that you followed to reach the answer?
MH: The number "10" was given in the question. So, I substituted "10" in the function: $3(10) + 7 = 37$.
For the item (18): State the independent and dependent variables?



The student (HM) used the numbers on the x-axis to express the independent and independent variables. He stated that the independent variable is “14” and “10” represents the dependent variable.
A: Can you explain why did you think that this process doing like this?
HM: We have a value “10” on x-axis represents the independent variable, also the value “14” is the dependent variable.
The student treats wrongly some values on x-axis as independent and dependent variables.
Some students described the graph generally when they asked to describe what does the y-intercept means for a given graph. For example, the student (SS) stated that the volume increases when the time increases.
A: Can you tell me how did you answer this question?
SS: I described the meaning of y-intercept. It is clear that the volume increases when the time increases.
The student didn’t distinguish between describing the meaning of y-intercept and graph.

Conclusion

As it was shown, Tenth Graders in the United Arab Emirates had a variety kinds of misconceptions in algebra. They had common conceptual errors in algebraic expressions, linear equations, polynomials, exponents and radical expressions, and functions and graphs. Students show that they stick of their previous concepts and defend them as if they were actually true. Students' responses showed that conceptual errors negatively affect students' performance and achievement in algebra.

The process of detecting conceptual errors is of great importance. Ignoring these misconceptions at one level causes them to accumulate in the learners' cognitive structure as they move to the next level. This means that the process of replacing these misconceptions with correct ones will be more difficult. In this paper, the authors worked on uncovering common conceptual errors among students at this level and presented a set of instruments used in this regard. They discussed the expected errors before implementation and then the thinking strategies associated with students' misconceptions that appeared during the test and the interviews. In this paper, the authorss presented the common misconceptions of Tenth graders in the United Arab Emirates, in addition to other types of these conceptual errors. The authors recommend the necessity of detecting these errors. Further research should focus on appropriate strategies to reduce and remedy them.

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