Fraction Skills as Predictor of Algebraic Proficiency

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Abstract

Fraction knowledge has long been correlated to algebra knowledge, but their association was unfamiliar in the mathematics instruction of the researcher's actual workplace. The current study aimed at determining the correlation that existed between fraction skills and algebraic proficiency among the grade 7 students of the three public secondary schools of Tagum City, including those at the researchers' workstation. The independent variable was fraction skills, while the dependent variable was algebraic proficiency. The research utilized a predictive correlational design and employed a quantitative, non-experimental approach to survey 357 participants. Mean, standard deviation, Pearson-r, and regression analysis were the statistical tools used to analyze the data gathered using an adapted-modified questionnaire as the survey instrument. The findings indicated a moderate positive correlation between fraction skills and algebraic proficiency. Moreover, each of the domains of fraction skills, e. g., relational understanding of fractions, fraction magnitude knowledge, and procedural knowledge, was also correlated to algebraic proficiency. It was revealed further that each of these domains of fraction skills was predictive of algebraic proficiency and that, if taken as a whole, fraction skills was predictive of algebraic proficiency, which implies that there was sufficient evidence obtained from the sample that a significant relationship existed between the variables.

Keywords: MAED – Teaching Mathematics, Fraction Skills, Algebraic Proficiency, Relational Understanding of Fraction, Fraction Magnitude Knowledge, Procedural Knowledge, Philippines

1. Introduction

1.1. Rationale

Difficulty in learning algebra is evident in mathematics pedagogy. Students find it hard to digest the concepts and procedures introduced to them. Hence, the search for the factors affecting this difficulty leads to the conduct of several experiments and research studies (Apsari et al., 2020; Habtamu et al., 2022; Sharpe & Marsh, 2022; Sugiarti & Retnawati, 2019).

The researchers emphasized that algebra serves as a "gatekeeper" to higher-level courses in mathematics. A thorough understanding of its concepts and procedures indicates a bright future in

mathematics. Failure to overcome this critical step, on the other hand, could result in poor future mathematical performance (Adam, 2018; Blanton et al., 2019; Sharpe & Marsh, 2022; Viegut, 2021).

In pursuit of the factors and prerequisite knowledge that have an association with algebra, researchers conducted several studies in order to identify them and determine which among them has the strongest correlation with algebra (Sharpe & Marsh, 2022). Amazingly, one of the variables (e .g., decimals, whole number arithmetic, etc.) that showed a close relation to algebra was fraction (Hurst & Cordes, 2018), even after the participants' IQ, background of the family, and working memory were controlled (Siegler et al., 2012, as cited in Braithwaite et al., 2022). This finding paves the way for other researchers to validate the previous studies and prove further that skills in fractions could possibly predict students' achievement in algebra (Anderson, 2021; Booth et al., 2014, as cited in Ubah, 2021).

As a mathematics teacher, the researcher has not encountered a study in his actual workspace that emphasizes the relationship between fraction and algebra in mathematics pedagogy. Hence, he wants to find out if this relationship exists in the learning experiences in mathematics among his research respondents, including his students. Moreover, if this study provides sufficient evidence of a positive correlation between fraction skills and algebraic proficiency and that the former has predictive power on the latter, then honing students' proficiency on fraction skills may significantly augment their proficiency in algebra.

1.2. Research Objectives

This study aims at determining which domain of fraction skills significantly predicts algebraic proficiency among grade 7 students in three public secondary schools in Tagum City. The following objectives are:

1. to describe the level of students' fraction skills in terms of the following:
    1.1 relational understanding of fraction,
    1.2 fraction magnitude knowledge,
    1.3 procedural knowledge;

2. to describe the level of students' algebraic proficiency in terms of the following:
    2.1 feature knowledge,
    2.2 equation solving;

3. to determine the significant correlation between fraction skills and algebraic proficiency; and

4. to establish which domain of fraction skills significantly predicts algebraic proficiency.

1.3. Hypotheses of the Study

The following are the hypotheses of the study:

1. There is no significant relationship between fraction skills and algebraic proficiency among grade 7 students in the three public secondary schools in Tagum City.

2. There is no domain in fraction skills that significantly predicts algebraic proficiency.

2. Methodology

2.1. Research Design

A quantitative, non-experimental research method employing correlational design and regression analysis was used in this study. This design was intended to determine the degree of correlation that existed between the predictor variable and the criterion variable. Moreover, this study utilized a prediction design, which is a type of correlational design that is used to show the predictive power of one variable on another variable (Apuke, 2017). With this design, the predicting ability of fraction skills on algebraic proficiency among the respondents was determined.

2.2. Population and Sample

The respondents of the study were the grade 7 students who were enrolled in three big public secondary schools in Tagum City for the school year 2021–2022. In school A, the grade 7 students reached 904 in number; in school B, there were 958 students; and in school C, the grade 7 students reached 1,431 in number. The total population of the respondents was 3,293.

Subsequently, cluster random sampling was used in the selection of participants for the study. With this method of sampling, the respondents were not selected individually from the entire population; instead, the selection was done by sections. Moreover, the research utilized Slovin's formula to determine the appropriate sample size for the respondents. Hence, the required number of respondents totaled 357.

Furthermore, the respondents were given the freedom to withdraw from their participation anytime if they felt threatened, physically uncomfortable, emotionally disturbed, or had any other similar feelings or conditions during the course of the research.

2.3. Research Instrument

The study employed a downloaded, adapted, and modified questionnaire. It was composed of the fraction skills test and the algebraic proficiency test. The whole test comprised 25 items, all in multiple-choice type with 4 choices, one of the modifications made by the researcher since some of the original questions did not contain 4 choices. Moreover, questions that were done as a task in the sources' studies (Booth et al., 2014, as cited in DeWolf et al., 2015) were done in the form of a test, and the fractions included were common fractions that were usually used as examples in the classroom setting. Other items under Fraction Skills were researcher-made questions based on the definition of fraction magnitude knowledge (Braithwaite et al., 2022; Malone et al., 2019; Rodrigues et al., 2019). All these modifications were made to contextualize the school setting and to suit the grade level of the respondents.

The pilot testing of the test was done with 50 respondents not included in the actual respondents of the test. The respondents' responses were subjected to a reliability test using Cronbach's alpha. The Fraction Skills test's Cronbach's alpha showed a value of 0.809, and its alpha based on standardized items showed a value of 0.808, which implies good interval consistency among the items. On the other hand, the Algebraic Proficiency Test's Cronbach's Alpha showed a value of 0.795, and its Cronbach's Alpha based on standardized items showed a value of 0.794, which indicates an acceptable interval consistency among the

items as stated by George and Mallery (2003), as cited in Gliem and Gliem (2003). Moreover, the questionnaire was content-validated by experts.

2.4. Statistical Treatment

This research employed statistical tools that are suited for correlation studies, such as Mean, Standard Deviation, Pearson-r, and Regression Analysis. The mean was employed in order to determine the levels of fraction skills and its three indicators, e.g., relational understanding of fractions, fraction magnitude knowledge, and procedural knowledge, as well as the levels of algebraic proficiency and its two indicators, namely, feature knowledge and equation solving. Moreover, the standard deviation was used in order to determine how far the data were from the mean in both fraction skills and algebraic proficiency. Furthermore, the study utilized Pearson's correlation coefficient (Pearson-r) to establish the correlation between the students' fraction skills and their algebraic proficiency, as well as the correlation between each domain of fraction skills and algebraic proficiency. Lastly, regression analysis was utilized in order to establish the predictive power of fraction skills on algebraic proficiency and also the predictive power of each of the domains of fraction skills on algebraic proficiency.

3. Results and Discussion

This section reveals the results of the study as well as the analysis and interpretations of the data, which are presented in both tabular and textual formats. Using a 0.05 level of significance, all inferential findings were examined, and their implications were assessed. Tables and their explanations were organized chronologically under the following subheadings: level of fraction skills in terms of relational understanding, fraction magnitude knowledge, and procedural knowledge; level of algebraic proficiency in terms of feature knowledge and equation solving; the correlation between fraction skills and algebraic proficiency; and the regression analysis on fraction skills as a predictor of algebraic proficiency, where the domains of fraction skills that significantly predicted algebraic proficiency were determined.

The standard deviation was used to determine the deviation of each response from the mean. It can be noted that the standard deviation, which ranges from 0.99 to 2.49 for a 5-point Likert scale, shows that some of the ratings obtained in the study are less than 1, which means that the data are close to the mean, indicating that the data are less spread out from the mean. On the other hand, some ratings obtained that are greater than 1 mean that the data are more spread out from the mean (Wittink and Bayer, 1994, as cited in Baria and Gomez, 2022).

3.1. Level of Fraction Skills

The mean scores for fraction skills, with an overall mean of 4.72 and a standard deviation of 2.49, which is described as unsatisfactory, are presented in Table 1. The unsatisfactory level is attributed to ratings obtained by the respondents from the three indicators, namely relational understanding of fractions, fraction magnitude knowledge, and procedural knowledge. The overall mean score was obtained from the following computed highest to lowest mean scores of the indicators: fraction magnitude knowledge with a mean score of 2.04, which is described as developing; procedural knowledge with a mean score of 1.55, which is described as unsatisfactory; and relational understanding with a mean score of 1.13, which is described as

unsatisfactory.

Table 1. Level of Fraction Skills

Indicators (5 items each)	$\bar{x}$	**SD**	**Descriptive Equivalent**
Relational Understanding of fraction	1.13	0.99	Unsatisfactory
Fraction Magnitude Knowledge	2.04	1.25	Developing
Procedural Knowledge	1.55	1.15	Unsatisfactory
Overall (15 items)	**4.72**	**2.49**	**Unsatisfactory**

This implies that the respondents experienced difficulties in comparing fractions (e. g., comparing similar fractions or dissimilar fractions), locating fractions or mixed number on the number line, performing the fundamental operations of fractions, performing steps in solving fraction problems, simplifying fractions, identifying equivalent fractions (i. e. fractions with the same value), multiplicative or division relations of fractions, inverse relations (i. e. when the denominator of a fraction increases, its value decreases), and identifying ratio relations (i. e. visualizing fraction as a ratio, whether it is part-to-part or part-to-whole ratio).

Several authors have reported parallel results to the current study, indicating that students often struggle with fractions. For instance, a study by Jordan et al. (2017), as cited in Vessonen et al. (2021), found that students, especially those with learning difficulties, made only small progress in learning fractions when they were included in the curriculum. Li (2021) supported these findings in his study, noting that students had difficulty differentiating between the functions of the numerator and denominator, comparing fractions, creating equivalent fractions, and justifying their reasoning in fraction multiplication, despite having already been introduced to the basic concepts of fractions in their elementary math curriculum.

3.2. Level of Algebraic Proficiency

The mean scores for algebraic proficiency, with an overall mean of 3.18 and a standard deviation of 1.74, which is described as unsatisfactory, are presented in Table 2. The unsatisfactory level can be attributed to the ratings obtained by the respondents in the indicators, namely feature knowledge and equation solving. The overall mean score is the result attained from the following computed mean scores of the indicators, which start from the highest down to the lowest: equation solving with a mean score of 1.90 with a standard deviation of 1.27, which is described as unsatisfactory; and feature knowledge with a mean score of 1.28 with a standard deviation of 0.99, which is described as unsatisfactory.

Table 2. Level of Algebraic Proficiency

Indicators (5 items each)	$\bar{x}$	**SD**	**Descriptive Equivalent**

Feature Knowledge	1.28	0.99	Unsatisfactory
Equation Solving	1.90	1.27	Unsatisfactory
Overall (10 items)	**3.18**	**1.74**	**Unsatisfactory**

This suggests that learners struggled with finding the value of the unknown in a linear equation in one variable, understanding the meaning of parts of an algebraic expression, understanding equivalent equations, and understanding important features such as the equality symbol, negative signs, variables, and constants.

The unsatisfactory results of the respondents' overall level of algebraic proficiency confirmed the findings of Pearn and colleagues (2019) and Thomas (2010), which showed low scores on algebra tests and indicated difficulties in learning the subject matter. These difficulties in learning algebra were also supported by the findings of Manandhar and colleagues (2022), which asserted that the abstract nature of algebra, including variables and constants, was the reason for its complexity. This complexity led teachers to rely on step-by-step procedures and algorithms to solve problems instead of discussing the underlying concepts.

3.3. Correlation between Fraction Skills and Algebraic Proficiency

One of the objectives of this study is to find out the correlation that exists between fraction skills and algebraic proficiency. In order to look into the correlation between these variables, Pearson-r was used. The findings of the analysis and interpretation of the substantial association between fraction skills and algebraic proficiency, which are expressed in numeric figures, are shown in Table 3.

Table 3. Correlation between Fraction Skills and Algebraic Proficiency

Independent Variable	$\bar{x}$	SD	Dependent Variable	$\bar{x}$	SD	r-value	p-value	Decision
Fraction Skills								
Relational Understanding of Fraction	1.13	0.99				0.407**	0.000	H_0 is rejected
Fraction Magnitude Knowledge	2.04	1.25	Algebraic Proficiency	3.18	1.74	0.422**	0.000	H_0 is rejected
Procedural Knowledge	1.55	1.15				0.414**	0.000	H_0 is rejected

r = 0.565** p-value = 0.000

**p<0.00 *p<0.05

It is observed in Table 3 that the values reveal the correlation between the two variables. With fraction skills' overall r-value of 0.565** being the coefficient of correlation, which is classified as moderate correlation (Schober et al., 2018), the overall p-value of 0.000, which is less than the alpha (α) value of 0.05, implies a positive correlation. Therefore, it was concluded that the hypothesis claiming the absence of a correlation between fraction skills and algebraic proficiency is invalid and thus rejected.

In order to extend further the investigation made on the significant relationship between fraction skills and algebraic proficiency, each domain of the fraction skills is being correlated with the algebraic proficiency. Table 3 discloses the values that show the correlations of each indicator of fraction skills with algebraic proficiency.

Being the first domain of fraction skills, relational understanding with a mean of 1.13 and a standard deviation of 0.99 was correlated with algebraic proficiency with a mean of 3.18 and a standard deviation of 1.74 and has an r-value of 0.407** and a p-value of 0.000, which is less than the alpha value of 0.05, which shows a positive correlation. Thus, the null hypothesis is rejected, and it is concluded that there is a significant relationship between relational understanding of fractions and algebraic proficiency. The second domain of fraction skills is fraction magnitude knowledge, with a mean of 2.04 and a standard deviation of 1.25, as correlated with algebraic proficiency, with a mean of 3.18 and a standard deviation of 1.74, which has an r-value of 0.422** and a p-value of 0.000, which is less than the alpha value of 0.05, which shows a positive correlation as well. This implies that fraction magnitude knowledge has a significant relationship with algebraic proficiency.

The third domain of fraction skills, procedural knowledge, with a mean of 1.55 and a standard deviation of 1.15, was the last to be correlated with algebraic proficiency, with a mean of 3.18 and a standard deviation of 1.74, and has an r-value of 0.414** and a p-value of 0.000, which is still less than the alpha value of 0.05, which shows a positive correlation as the two preceding domains. Hence, the decision is also to reject the null hypothesis, implying that both procedural knowledge of fractions and algebraic proficiency have a significant relationship.

The findings of the current study paralleled the findings of various studies which also stressed that fraction knowledge has positive correlation with algebra knowledge. Siegler and colleagues (2012) as cited in Braithwaite et al. (2022) stated that correlation between fraction knowledge and algebra knowledge exists even students' IQ, economic status, and educational background are being controlled. Additionally, because of this strong connection between fraction and algebra, Anderson (2021); Booth et al. (2014), as cited in Viegut (2021); and Rodrigues et al. (2017), all suggested that in order to prepare pupils in learning algebra, it is imperative to develop first their understanding of fractions.

Additionally, the current study's findings also supported the results of the studies conducted by Aldrich (2015), Bentley and Bosse (2018) and Powell et al. (2019), as cited in Viegut (2021). In their studies they emphasized that knowledge on fraction is critical to learning much more complicated algebra knowledge. They added that even college students still rely on their strong foundation of fraction knowledge, which they

learned in elementary and in high school levels, when it comes to learning higher algebra. Additionally, Siegler et al. (2012), as cited in Hurst and Cordes (2018) found out in their study that the association between proficiency in fractions and competence in algebra still existed even fraction knowledge was acquired several years before the algebra was learned. Hence, the studies of these authors confirmed that the connection between understanding of fractions and algebraic proficiency in earlier instructions still holds even as learners progress into adulthood and reach college.

3.4. Regression Analysis of Fraction Skills as Predictor of Algebraic Proficiency

Table 4 presents the regression analysis on fraction skills as a predictor of algebraic proficiency. It also presents the regression analysis of each domain of fraction skills with algebraic proficiency. The table shows a computed F-ratio of 55.592, which implies that the difference between the two variables is significant, and an overall P-value of 0.000, which indicates that fraction skills significantly predict algebraic proficiency. The overall R-value of 0.566 shows a moderate positive correlation between the two variables (Schober et al., 2018), with an overall R2 of 0.321 as the coefficient of determination, which indicates that 32.1% of the algebraic proficiency is explained by fraction skills and that the remaining percentage may be attributed to other factors outside the scope of the study.

The table shows further that relational understanding being the first domain of fraction skills with a beta of 0.270 and a p-value of 0.000, which is less than the alpha value of 0.05, indicates that it significantly predicts algebraic proficiency. Additionally, with a beta of 0.261 and a p-value of 0.000, fraction magnitude knowledge significantly predicts algebraic proficiency as well. Finally, procedural knowledge, with a beta of 0.243 and a p-value of 0.000, also implies that it significantly predicts algebraic proficiency.

Table 4 Regression Analysis on Fraction Skills as Predictor of Algebraic Proficiency

Independent Variable:	**Unstandardized Coefficients**		**Standardized Coefficients**	**t-value**	**Sig. (p-value)**	**Decision**
Fraction Skills	B	Std. Error	Beta			
(Constant)	1.327	0.165		8.026	0.000	
Relational Understanding	0.475	0.082	0.270*	5.816	0.000	H_0 is rejected
Fraction Magnitude Knowledge	0.365	0.067	0.261*	5.455	0.000	H_0 is rejected
Procedural Knowledge	0.370	0.073	0.243*	5.059	0.000	H_0 is rejected

Dependent Variable: Algebraic Proficiency

R = 0.566*	R^2 = 0.321
F-ratio = 55.592	P-value = 0.000

In summary, Table 4 reveals that each domain of fraction skills has a p-value that is less than the alpha value of 0.05. This means that each domain of the fraction skills predicts algebraic proficiency.

The results on the regression analysis on the variables of the study indicated that each of the domains of fraction skills, e.g., relational understanding of fraction, fraction magnitude knowledge, and procedural knowledge, predicted algebraic proficiency. Subsequently, when taken as a whole, fraction skills predicted algebraic proficiency, implying that students who performed well with fractions tend to perform well also with algebra, and those who performed poorly with the former tend to perform poorly also with the latter.

The outcomes of the current study confirm the findings of Booth et al. (2014), DeWolf et al. (2015), Hurst and Cordes (2018), Pearn & Stephens (2016), Viegut (2021), and Young & Booth (2020). In their works, they claimed that algebraic proficiency is predicted by fraction knowledge. This is supported by Siegler et al. (2012), who found in their study that fraction knowledge was the best predictor of algebra knowledge while controlling for other variables such as economic status, students' IQ, and working memory. The authors also noted that the fraction skills acquired during elementary school remained predictive of algebraic proficiency even in college years, indicating that the capacity of fraction comprehension to predict performance in algebra is not contingent on the recentness of instruction in these concepts.

4. Conclusion

After considering the study's objectives, the researcher concluded that students' level of fraction skills and algebraic proficiency was unsatisfactory. Additionally, a significant moderate positive correlation was found between fraction skills and algebraic proficiency. Moreover, each domain of fraction skills, such as relational understanding of fractions, fraction magnitude knowledge, and procedural knowledge, predicted algebraic proficiency. Furthermore, when considered together, fraction skills as a whole were found to predict algebraic proficiency.

The current study’s findings confirmed the proposition of Wu (2001) and other researchers that fraction knowledge has a positive association with algebra knowledge. Wu and other authors, in their findings, suggested that to better prepare the students in their learning in algebra, they may better be equipped first with all necessary facets of fractions.

5. Recommendation

After carefully examining the results and conclusions of the present study, the researcher has developed several recommendations. These include practical measures that educators can implement to enhance students' algebraic competence, proposals for vital actions that DepEd officials and curriculum

planners can take to address prevalent issues in teaching mathematics, particularly those related to fractions and algebra. Furthermore, the study has identified gaps that need further exploration by future researchers.

Firstly, to increase students' proficiency in fractions, teachers may focus on teaching the relational concepts of fractions. For instance, when understanding fractions as operators, students may visualize splitting a number n into two before deciding whether to divide it by 2 or multiply it by 1/2. Additionally, it may be stressed that a fraction has an infinite number of equivalent fractions and that the value of a fraction remains constant as long as the original ratio is maintained. It may also be helpful to clarify how to reduce fractions to their lowest terms. When understanding fractions as inverse relations, it is important to emphasize that the denominator has an inverse relationship with the value of the fraction, unlike the numerator. As the denominator increases, the value of the fraction decreases, and vice versa. Finally, when understanding fractions as ratios, visual illustrations can aid students in visualizing the problem.

Along with improving students' fraction skills, it is recommended to enhance their knowledge of fraction magnitude. This can be achieved through activities and drills focused on locating fractions on the number line. It is important to note that fractions or mixed numbers are positioned between integral values on the number line. Additionally, an infinite number of fractions and mixed numbers can be found between any two consecutive whole numbers. By learning to locate these fractions, students can develop a clear understanding of fraction as a whole magnitude, rather than separate values of the numerator and denominator.

Furthermore, it is recommended to enhance students' understanding of procedures and arithmetic involving fractions to improve their fraction skills. This can be accomplished through constant practice and familiarization with the steps required to perform fundamental fraction operations and to solve problems involving fractions. One way to promote familiarity with these procedures is to integrate music or poetry into the lesson, allowing students to create their original compositions. Another approach is to introduce fraction operations in board games, such as DAMATH, which is typically played by a few players during math contests. By incorporating this game into the lesson and allowing ample time for practice, the whole class can gain mastery of fraction procedures and arithmetic. Students may even be encouraged to play the game during their free time.

Secondly, to increase students' proficiency in algebra, teachers should focus on enhancing their knowledge of algebraic expressions and equations. This can be achieved through targeted exercises that help students understand the significance of various components, such as the equals sign, negative signs, and variables. Group activities that encourage brainstorming and exploration of these features can also be effective.

In addition, it's important to improve students' ability to solve equations. This can be accomplished by providing them with ample practice problems that require finding the value of the unknown, and giving them opportunities to explain their methods for arriving at the solutions. By following these strategies, teachers can help their students achieve proficiency in algebra and build a strong foundation for future math studies.

Thirdly, educators, DepEd officials, and curriculum planners are recommended to explore strategies and competencies that focus on the effective teaching of fractions, as they are an essential prerequisite to mathematics instruction. Organizing seminar-workshops, implementing innovative instructional strategies,

and consistently monitoring how fractions are taught can be beneficial for learners in developing their fraction skills. These skills have been shown to be essential for improving proficiency in algebra.

Lastly, in future research, it is recommended that more indicators of both fraction skills and algebraic proficiency be identified, to establish a stronger positive association between these variables. Although the current study confirms the propositions of other researchers - that fraction skills predict algebraic proficiency - the moderate positive correlation between the variables in this study shows slight inconsistency with other studies that claim a strong positive correlation between the two variables. This may be due to the limited indicators used in this study. Therefore, identifying more specific and reliable indicators can help to close this gap in knowledge. By following these guidelines, future researchers can build on the insights gained from previous studies and further advance our understanding of the relationship between fraction skills and algebraic proficiency.

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