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Predicting Physics Achievement of 11th - grade Students through Critical and Logical Thinking Skills

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Abstract

The purpose of this study was to measure the extent to which critical thinking skills and logical thinking skills predicted the achievement in physics of 11th - grade students in Gaza. To this end, (215) students participated in the study. California Critical Thinking Skills Test (CCTST) and Test of Logical Thinking (TOLT), were used as data collection tools in the study. Data were analyzed by multiple stepwise regression analysis. Results indicated that the students' scores of probabilistic reasoning and proportional reasoning (as logical thinking skills), and inference (as critical thinking skill) were significant predictors of physics achievement scores, explaining (15.7%) of the variance of physics achievement scores. In addition, findings indicated that the best predictor was probabilistic reasoning, explaining (9.2 %) of the variance. The study recommended that a physics curriculum should involve thinking skills, which predict students' achievement in physics.

Key words: Logical thinking skills, critical thinking skills, physics achievement, regression analysis.

التنبؤ بتحصيل طلبة الصف الحادي عشر في مبحث الفيزياء من خلال مهارات التفكير الناقد والتفكير المنطقي.

الملخص:

هدفت الدراسة إلى قياس مدى تنبؤ مهارات التفكير الناقد ومهارات التفكير المنطقي بالتحصيل الدراسي لطلبة الصف الحادي عشر – فرع العلوم– في مبحث الفيزياء، و شارك في الدراسة (215) طالباً تم اختيارهم من المدارس الثانوية في غزة، كما تم استخدام اختبار كاليفورنيا لقياس مهارات التفكير الناقد، واختبار قياس مهارات التفكير المنطقي . تم تحليل البيانات باستخدام تحليل الانحدار الخطي المتعدد. أسفرت النتائج أن الاستدلال (كأحد مهارات التفكير الناقد) و المنطق الاحتمالي و المنطق التناسبي (من مهارات التفكير المنطقي) هي متغيرات منبئة بدرجة دالة احصائياً بتحصيل الطلبة في الفيزياء وهي تفسر (15.7%) من التباين في تحصيل الطلبة في الفيزياء. بالإضافة إلى ذلك فقد توصلت الدراسة إلى أن المنطق الاحتمالي أفضل متغير منبئ حيث أنه

كلمات مفتاحية: مهارات التفكير المنطقي، مهارات التفكير الناقد،التحصيل في الفيزياء، تحليل الانحدار.

Introduction:

The twenty-first century has represented various challenges for students. Thinking skills are considered the most important requirement for these challenges because they empower students to effectively participate in the development of their school's activities and social lives. In an expanding world of information, there is a growing need for students to deal with information, assess thoughts, and reason through arguments (Fong, Kim, Davis, Hoang, & Kim, 2017). In other words, students must think critically if they want to succeed. In 1929 the philosopher Alfred Whitehead noted, "Your learning is useless to you till you have lost your text, burnt your lecture notes, and forgotten the minutiae you have learned by heart for the examination". His observation indicates that the true outcomes of education are "the thought processes that result from the study of a discipline, not the information accumulated"(Profetto-McGrath, 1999). Accordingly, critical thinking and logical thinking skills today are underscored as the central twenty-first-century skills. It is widely assumed that the development of these skills should be an important aim of education.

In recent years, the topic of the relationship between critical thinking and logical thinking skills and students' achievement has continued to attract the consideration of researchers. Most of the research results are unequivocally agree about the connection between logical thinking, critical thinking, and academic achievement. Several studies have shown that there is a relationship between critical thinking and academic achievement (Semerci,2011; Ramos et al., 2013; Sherafat, 2015), although, Aksu & Koruklu (2015) have argued that there is no significant relationship between critical thinking dispositions and academic achievement. In contrast, while some studies suggested that logical thinking predicts students' achievement (Vázquez & Anglat, 2017; Gurcay & Gulbas, 2018; Rakhmawan, Firman, Redjeki, & Mulyani, 2018), other studies pointed in the opposite direction (Hejnová et al., 2018; Riyanti, Suciati, & Karyanto, 2019). There is a limited agreement between studies, about what thinking skills predict students' achievement? Most of these studies focused on the academic achievement of university students, and their focus is restricted to critical thinking and logical thinking as a whole ability. Overall, it has remained unclear whether all skills of logical thinking and critical thinking can predict academic achievement.

In support of the significant role of critical thinking in improving learning outcomes in general, many researchers found that the teaching of critical thinking skills in conjunction with subject areas improved students' academic achievement (El-Koumy, 2019). In 2020, the world institute for advanced research and science (W.I.A.R.S.) organized virtually the international psychological applications conference and trends (InPACT), the most important recommendation was to merge critical thinking into the different education programs from an early age, for more practice. Because smart technique will lead to smart outcomes that will serve societies in general (Pracana, Clara & Wang, Michael, 2020). In the same year, the International Association for the evaluation of educational achievement (IEA) in Germany, reported on a study that examined student errors and misconceptions in physics and mathematics, across education systems of five countries (Italy, Norway, Russian Federation, Slovenia, and the USA) on 20 years of data (1995–2015) from TIMSS at grades four and eight, and TIMSS Advanced (grade 12). The results revealed that there were some misconceptions and misunderstandings that were demonstrated by at least one-third of students. The study recommended that instruction across the grade levels needs to include more different types of application problems.(Neidorf, Arora, Erberber, Tsokodayi, & Mai, 2020)

Undoubtedly, the ability of students to apply the information to solve new problems will improve if that information is obtained through higher-order thinking processes because it will more easily transferable and comprehensive (Ramos, Dolipas, & Villamor, 2013). As a result, the physics curriculum should be underpinned by the most effective critical thinking and logical thinking skills to enhance student's achievement and to successfully face the challenges of the

twenty-first century (El-Koumy, 2019; Profetto-McGrath, 1999). Physics is considered one of the most important sciences and a significant factor in making progress, technology, and industry (Ramos et al., 2013). Up to now, many countries have tended to focus on creating generations to think like physicists, in other words, to be a physicist you must think critically and logically (Main, 2014). However, the Palestinian educational foundations fail to achieve this aim. The clearest indication of this failure is that Palestinian students accept the information they get without ensuring its soundness and its sources. Another manifestation is that Palestinian students avoid joining the science branch in public schools (Awdallah, 2011). A last but not the least manifestation is that Palestinian students shift the specialty from science faculty to other faculties, and most of them avoid enrolling in specializations of physics, chemistry, and mathematics in Palestinian universities because they think that physics is one of the most difficult subjects at school curriculum. (Alajaz, 2008; Alqassim, Abu Saa, & Awwad, 2019). The failure of developing critical thinking and logical thinking skills in Palestinian students is attributable to the superficiality of curriculum content. According to AbuMhadi(2011) study, the eleventh and twelfth grades physics syllabuses content of 2008-2009 in Palestine, contain poor ratios of critical thinking skills, the results revealed also that the level of Palestinian students acquisition of critical thinking skills was immediate or even weak. The most important question is that if the levels of Palestinian students in physics, critical thinking, and logical thinking were improved after they learned the new physics curriculum since the academic year 2017/2018. According to the general educational indicators issued by the Palestinian Ministry of Education in 2020, the proportion of students enrolled in the scientific branch in secondary schools was (28%), while the proportion of students enrolled in the Literary branch was (66%) (Education, 2020). These indicators may support the argument that students face difficulties in scientific subjects, therefore most of them avoid enrolling in the science branch in secondary schools.

Therefore, this study aims to identify more specifically, how, critical thinking skills and logical thinking skills can predict the physics achievement of 11th-grade students. The importance and originality of this study are that it employed advanced statistical technique such as multiple stepwise - regression analysis, matters not only to predict physics achievement but also to decide how to explain the variance of students' achievement in physics by the most effective critical thinking skills and most effective logical thinking skills. The most interesting thing is that besides adopting the Test of Logical Thinking (TOLT), this study adopted the California Critical Thinking Skills Test (CCTST) (The Palestinian version) that introduces - to policymakers and teachers- standard evaluation to measure critical thinking skills of Palestinian students.

The Statement of the Problem

Since the document of the first Palestinian curriculum in 1998, the Palestinian ministry of education efforts is in progress to raise the level of students' achievement in physics. Accordingly, as the Palestinian government is more profoundly concerned for the final student outcomes, the ministry is forced to think in terms of "quality inputs to quality outputs" to improve the students' achievement in physics. In this context, one of the most basic inputs that must be embedded in the physics curriculum is thinking skills. Within the framework of the development of science curricula, the Palestinian ministry of education has decided to teach the physics textbook for the 11th grade in Palestine at the academic year 2017/2018, The Authors of the physics textbook said that ''the philosophy of the book is inspired by the importance of acquiring a scientific methodology in thinking and work, and the development of mental and practical skills''(Palestinian Ministry of Education, 2018). Based on the main researcher's experience in teaching physics many years ago in public schools in Gaza, it was observed that low levels of student's achievement in physics, the same thing happens in most schools and universities in Gaza. This reality is easy to

investigate by studying and analyzing students' scores in physics. One of the most features of this problem is the decreasing number of students enrolled in the science branch, compare with increased dropout rates and the shift to the literary branch.

Reviewing the related literature, the researchers realized the knowledge gap as no studies used multiple regression analysis to answer the question of what specific critical thinking skills and logical thinking skills are more relevant than others to predict physics achievement of 11th-grade students. Therefore, there is a need for additional studies to investigate the predictive role of logical thinking skills and critical thinking skills on the physics achievement of 11th-grade students.

The Study Question

The problem of the study is represented in the following question:

What is the predictive role of critical thinking skills and logical thinking skills on the physics achievement of 11th-graders?

The Purpose of the Study

The current study is mainly conducted to investigate the predictive role of critical thinking skills and logical thinking skills on the physics achievement of 11th-graders.

The Significance of the Study

Applications of regression techniques in education are fairly recent in many Arab countries. Although many modeling studies were conducted to investigate the affective factors related to science achievement in non-Arab universities, no research has been conducted to explore what specific critical thinking skills and logical thinking skills influence physics achievement. The importance of the current study relies on the implications that may help physics educators and instructional designers. The significance of the current investigation can be summarized as follow:

- ✓ This the first study which employs advanced statistical technique such as multiple regression to explain how can predict physics achievement of 11th-graders by critical thinking skills and logical thinking.
- ✓ The results of this study may provide an in-depth understanding of the critical importance of the most affecting critical thinking skills and logical thinking skills success in physics achievement.
- ✓ These findings might be beneficial for many teachers who seek to improve their students' achievement in physics.
- ✓ In light of the multiple regression equation that emerged in this study, considerable suggestions can be provided for teachers, instructional designers, curriculum development centers, and physics education researchers, about how can improve physics achievement by the effective thinking skills, and what thinking skills must be embedded in the physics curriculum.
- ✓ The results may show evidence for the relationships between critical thinking skills, logical thinking skills, and physics achievement which will provide an impetus for the enrichment of more inclusive strategies to create supportive teaching environments for teachers and effective learning environments for students.
- ✓ The CCTST (The Palestinian version) can help the teachers to determine the critical thinking skills of their students.

Definitions of Terms

Physics Achievement (PA) is defined, in this study, as the score of 11th-graders which are identified based on the standardized final physics exam.

Critical Thinking (CT) is defined as an intentional self-regulatory judgment that brings about interpretation, analysis, evaluation, and inference, as well as an explanation of the evidential, conceptual, methodological, or contextual considerations upon which that judgment is based (P. A. Facione, 1990). In this study, this term refers to the ability of 11th -graders to analysis, evaluation and inference, and can be measured by the California Critical Thinking Skills Test (CCTST) (The Palestinian version). The analysis, evaluation, and inference skills are based on the conceptualization of the Delphi Report (1990) sponsored by the American Philosophical Association. (Facione & Facione, 1994).

Logical Thinking (LT) is defined by Lawson (1993) as the ability of an individual to use concrete and formal operational reasoning. (Stamovlasis, Kypraios, & Papageorgiou, 2015). In this study, this term refers to the ability of 11th -graders to control variables, proportional reasoning, probabilistic reasoning, and correlational reasoning, and can be measured by the Test of Logical Thinking (TOLT). These skills are based on the conceptualization of Tobin & Capie (1981) study.

Literature Review

Dewey considered thinking as developmental, however not of the need to age. According to him, thinking is created by progressing from concrete to abstract. According to Piaget thinking is founded on experience, and based on age. "Intelligence is the product of the innate potential interacting with the environment"(Padmanabha, 2018). In 1928 Piaget's theory of cognitive improvement clarified intellectual advancement in four stages: the sensory-motor, the pre-operational, the concrete operational, and the formal operational. in the final stage, the child can solve hypothetical problems by deductive logic and in a systematic method. Vygotsky provided an important angle on the social origins of thinking. He suggested that social communication assumes an essential role in the process of cognitive development. (Padmanabha, 2018).

According to Piaget, logical thinking refers to "the mental operations one uses in the face of certain problems".(Özdemir & Övez, 2017). Critical thinking a necessary skill for education according to Dewey (1916). He described critical thinking as a reflective procedure and "includes the sense of the problem, the observation of conditions, the formation of rational elaboration of a suggested conclusion, and the active experimental testing". (Saeger, 2014)

Many structural and regression models were tested to examine the relationships among physics achievement as a dependent variable and several variables like inquiry, mathematical thinking skills, thinking styles, and gender. (Hung, 2010; Yeo & Chong, 2012; Zhang, 2001; Mkpanang, 2016). Another important body of literature is focused on critical thinking and logical thinking as predictors of physics achievement.

The Relationship between Critical Thinking and Physics Achievement

Various models have surfaced in the literature attempting to explain the effect of independent variables as self-efficacy, classroom environment, psychological and intellectual characteristics of students, metacognitive and self-regulation on critical thinking as dependent variable (Uzuntiryaki-Kondakçi & Çapa-Aydin, 2013), (Prayoonsri, Tatsirin, Suntorapot, & Jariya, 2015) and (Gurcay & Ferah, 2018). Likewise, Alkharusi, Sulaimani, & Neisler (2019) indicated that the English language subject score, math subject score, and performance, were predictors of the critical thinking ability, after stepwise multiple linear regression analysis of data of 9809 students entering Sultan Qaboos University in Oman. However, the findings did not imply causal relationships between critical thinking and student achievement. Conversely, a little body of literature considers critical thinking as an independent variable and studies its effect on other variables such as metacognition (Arslan, 2015).

Although, Aksu & Koruklu (2015) have argued that there is no significant direct effect of critical thinking dispositions on mathematics achievement of Adnan Menderes University students

in Turkey. Few researchers have argued that critical thinking is a predictor of student performance, for instance,(Semerci, 2011) study demonstrated that critical thinking is a significant predictor of achievement-focused motivation. The regression analysis has been done. The study sample included a total of (772) students of universities in Turkey, and the critical thinking scale was CCTDI. Similarly, Sherafat (2015) indicated that there is a significant relationship between critical thinking and academic achievement, but the correlation is weak. Sherafat (2015) analyzed the data of 625 students from high schools in India by Pearson's correlation coefficient, Spearman's rho coefficient, and ANOVA. She concluded that critical thinking enhanced academic achievement. Further, in a follow-up study(Fong et al., 2017) that conducted a meta-analysis to synthesize the extant literature from a total of (23) pieces of research (27 samples, N = 8,233). The researchers found that critical thinking had a relationship with a student's achievement. Recently, Akpur (2020) found that critical thinking predicted significantly academic achievement. By the Critical thinking Scale, Akpur gathered data of (227) students of İstanbul university in Turkey and he applied SEM. Akpur did not attempt to assess academic achievement through a standardized test, instead of that, he adopted the overall average of students' grades. One study has been developed to explore the interrelation among components of critical thinking and physics achievement, Ramos, Dolipas, & Villamor (2013) conducted simultaneous multiple regression and collected data of (393) students of Benguet State University in the Philippines by test consisting of (60) multiple-choice types of questions. They showed that analysis, inference, and evaluation as higher-order thinking skills (HOTS), significantly influence the physics performance of students.

Several researchers as discussed above have investigated critical thinking and its components, most of them provide substantial evidence in favor of the positive interrelation between critical thinking and academic achievement. The review of these studies revealed that the context of the assessments mainly focused on the academic achievement of university students, and rarely on the academic achievement of secondary school students. This study particularly focuses on the physics achievement of secondary students. Another limitation of several studies is that their only indicate the unilateral relationships among critical thinking and academic achievement, which cannot explain to what extent the components of critical thinking influence physics achievement, only (Ramos et al., 2013) study considered analysis, inference, and evaluation as higher-order thinking skills (HOTS) as independent variables in regression analysis. This study conducted a stepwise regression analysis to investigate the relationship between analysis, inference, evaluation, and physics achievement. Besides, despite (Ramos et al., 2013) study, these studies measured critical thinking dispositions by scales. This study measured critical thinking skills by the California Critical Thinking Skills Test (CCTST) which was not used by any of the afore-cited studies.

The Relationship between Logical Thinking and Physics Achievement

Numerous specialists have referred to logical thinking as a reliable indicator of achievement in mathematics and science. Tobin & Capie (1981) reported that logical thinking, as assessed with the TOLT, is significantly related to science achievement in middle school students (Trifone, 2016). There is an important body of literature that followed tried to analyze more in-depth potential relationships between academic achievement and logical thinking. Although some researchers have argued that no significant correlation between logical thinking and academic achievement, for example, Hejnová, Eisenmann, Cihlář, & Přibyl (2018) surveyed (23) students from one class of the ninth grade, in the Czech Republic, they assessed students' reasoning abilities by LCTSR test, they used Spearman's rank correlation coefficients, they reported that the school performance in physics, largely do not correlate with proportional reasoning, control of variables, correlation reasoning, and probability reasoning. The researchers believed that this fact is related to the size of the study sample and it ought to hence be the subject of further research with a considerably bigger

arrangement of students. Likewise, Riyanti, Suciati, & Karyanto (2019) reported that there is no significant relationship between logical-thinking ability and science achievement of (33) middle school students in grade VIII in Indonesia.

A growing body of research indicates that logical thinking is a powerful predictor of student achievement. As far as is known, the first regression model was developed by Bitner-Corvin (1988). He analyzed data of (173) sixths through twelfth-grade students in the USA. He used the Group Assessment of Logical Thinking GALT. He reported that the five logical thinking modes were predictors of academic achievement. In the same approach, (Vázquez & Anglat, 2017) study was carried out on a sample of (709) first-year engineering students from the Argentine university. They found that entrance exams and TOLT scores explained 26% of the variance in physics achievement. By the same test of logical thinking ability, Gurcay & Gulbas (2018) used also, multiple stepwise regression analysis, one sample consists of (120) high school students in Turkey. They found that students' logical thinking ability scores explained (33%) of the variance related to the students' understanding of heat, temperature, and internal energy concepts, which included as the first subject in the curriculum of the 11th-grade Physics course. They indicated that students who are better at thinking processes such as controlling variables, proportional thinking, probabilistic thinking, relational thinking, and combinational thinking may learn physics better. Therefore, physics teachers need to create opportunities for students to develop their thinking abilities while designing learning environments. Likewise, Stamovlasis, Tsitsipis, & Papageorgiou (2010) applied the random walk model to analyze the data of (329) students of ninth-grade junior high school in Greece, which is collected by Lawson paper-and-pencil test of formal reasoning. They reported that logical thinking was the stronger significant predictor of understanding the structure of matter. By the same measurement tool, but in a different approach, another model testing study was conducted by Stamovlasis et al. (2015) they tested three models: a confirmatory factor model, a multiple-indicator multiple-cause (MIMIC) model, and path analysis, on the sample, consists of (374) students of secondary public schools in Greece. SEM analysis supported the hypothesis that logical thinking predicts science achievement in understanding the nature of matter and its chemical changes. The results of the path analysis model by Aksu & Koruklu (2015) also showed that there was a statistically significant direct effect of logical thinking upon mathematics achievement. They used the logical thinking skills inventory (LTSI). Aksu & Koruklu recommended that curriculum development specialists must revise Mathematics course books to consider critical thinking and logical thinking skills. Similarly, Rani (2018) analyzed -by Pearson's coefficient of correlation- data of (225) secondary school students from India which is collected by the reasoning ability of secondary school students scale developed by the investigator herself. She reported that there was a significantly high positive correlation between reasoning ability and academic achievement.

In the same approach, Rakhmawan et al. (2018) collected data by TOLT from a sample of (242) persons of 11th-grade high school students in Indonesia, they found that logical thinking ability had a significant relationship with students' achievement in chemistry. But in reality, only (26%) of the students have entered the formal development stage of logical thinking.

It is apparent that the studies outlined here produced the same results, that logical thinking predicts science achievement, except (Hejnová et al., 2018) and (Riyanti et al., 2019) studies. The differences in results may be attributable to such factors as types of assessment, sample selection techniques, and sample size. The review of these studies revealed that only (Vázquez & Anglat, 2017),(Gurcay & Gulbas, 2018), and (Rakhmawan et al., 2018) used TOLT, other studies used different tests and revealed the same results that logical thinking had a significant relationship with science achievement. Another limitation of several studies is that their focus is restricted to logical

thinking as a whole ability, except (Bitner-Corvin, 1988) study which was entered into the five modes of logical thinking into regression analysis. Although Corvin measured logical thinking by GALT, he considers the dependent variable is science achievement. This study measured logical thinking by TOLT, and consider the dependent variable as physics achievement.

Summary and Critical Analysis of Literature Review

The review of the literature demonstrated that the previous studies focus on two fundamental ways. While some studies investigated the relationship between critical thinking and student achievements, other studies examined the connection between logical thinking and student achievement, all of them made important contributions to the development of the current model which based on concepts of critical thinking regarding the Delphi Report (1990), and logical thinking regarding Tobin & Capie (1981).

Moreover, the research trends have been developed to clarify how student achievement is influenced by critical thinking or logical thinking, there is little agreement about what thinking skills are specifically. This study considered critical thinking skills and logical thinking skills as essential components to enhance the physics achievement of 11th-graders.

Although this study is aligned to the research trend that considers critical thinking skills and logical thinking skills as essential components in predicting physics achievement, there is a significant difference between this study and those that investigated critical thinking and logical thinking effect on student achievement. The knowledge gap in the current literature is that no study conducts multiple regression analysis to predict physics achievement by critical thinking skills and logical thinking skills together, and definitively answers the question of what specific skills are more relevant than others. With this in mind, this study tried to make specific contributions to the current effort to identify more specifically, how, critical thinking skills and logical thinking skills can predict the physics achievement of 11th-graders.

The Study Approach and Design

The study aims to measure the predictive role of critical thinking skills, logical thinking skills on physics achievement of the 11th-graders. Since the purpose of the study is to describe current circumstances about the sample to predict physics achievement, the predictive model was used. A bivariate Pearson correlation analysis was performed to assess the strength of the individual relationship between the variables. After that, inferential statistics such as the stepwise - multiple regression analysis was used to assess how well the predictors were able to predict physics achievement. In this study, there are seven predictor variables: analysis, evaluation, inference, the control of variables, proportional reasoning, probabilistic reasoning, and correlational reasoning.

The Sample of the Study

The target population of this study consists of all 11th-grade secondary school students in Gaza who enrolled in the science branch during the academic year 2019/2020. The results of the present study are generalized for this population. The total number of 11th -graders in secondary schools in the Gaza and North Gaza is almost (5592) (53% females and 47% males). (The Ministry of Education, 2019)

A priori sampling procedure was applied by G* power 3.1.9.4 program, to calculate the minimum sample size required for multiple linear regression analysis, as shown in the table below:

Table (1): A-priori sample size

Parameters	Value
Alpha level	.05
Predictors	5
Desired statistical power level	.95
Anticipated effect size (f2) (medium)	.15
The minimum sample size required	74

According to Hair, Joseph, and Black (2014), the minimum ratio of observations to variables is 5:1 for multiple linear regression analysis, the desired level is between (15) to (20) observations for each independent variable. When this level is reached, the results should be generalizable. However, if a stepwise procedure is employed, the recommended level increases to 50:1. In the present study, the number of independent variables is five, because evaluation and analysis variables were neglected for low their correlations with physics achievement, consequently, the sample size required for generalizing the result of the multiple linear regression analysis is (100) to (250). The researchers randomly selected Arafat Gifted Secondary Schools, and Blqys Alymn Secondary School in Gaza, and randomly selected two classes from every school, as shown in the table below:

Table (2): Frequency and Percentages of Students' Sample

School	f	%
Arafat Gifted Secondary School for boys	76	33.33
Arafat Gifted Secondary School for girls	76	33.33
Blqys Alymn Secondary School for girls	76	33.33
Total	228	
Missing	13	5.7
Total	215	

The sample of this study was (228) (152 females and 76 males) 11th- graders - the science branch in West Gaza, which approximately represents the population. Of all the students, (13) (5.7%) who participated in CCTST and did not participate in TOLT were considered missing data. Considering that, (215) participants involved in the current study were appropriate for the data analysis, multiple linear regression- stepwise, to investigate the thinking skills of sample members and its effects on their achievement in physics.

Based on the prior sample size display above, which required generalizing the results of the multiple linear regression analysis with acceptable effect size and power level, a post-hoc power analysis was calculated according to the following regression model:

$$\hat{Y} = B0 + B1X1 + B2X2 + B3X3 + B4X4 + B5X5$$

Where: $\hat{Y}$ =Physics Achievement score PA, B0 = constant (Intercept), Bs = Regression weights,

X1 = Inference, X2 = Proportional Reasoning, X3 = The Control of Variables,

X4= Probabilistic Reasoning, X5 = Correlational Reasoning.

According to the table of (Hair et al., 2014), sample sizes of (100) will detect variance explained (R square) value (12%) with 5 independent variables, Power of (0.80), and a significance level of (0.05). However, if the sample size (250) observations in these situations, the minimum (R square) (5%).

By convention, the effect size of (0.02), (0.15), and (0.35) are considered small, medium, and large respectively. The desired statistical power level should be greater or equal to (0.8). The alpha level must be less or equal to (0.05) to claim statistical significance. With these criteria, to improve generalizability and addresses both model parsimony and sample size concerns, a post-hoc power analysis was calculated by the G* power 3.1.9.4 program, for the multiple regression test, as shown in the table below:

Table (3): Post-Hoc power analysis calculation for multiple regression

Parameters	Value
Sample	215
Predictors	5
Alpha level	.05
Effect Size	.15
Power	0.999
Degrees of Freedom	209

Data Collection Instruments

The researchers used two instruments, the California Critical Thinking Skills Test (CCTST) and the Test of Logical Thinking (TOLT).

California Critical Thinking Skills Test (CCTST)

The CCTST was developed by Facione and used to measure the participants' critical thinking cognitive skills. This standardized test is composed of (34) multiple-choice items. The CCTST consisted of six scores including an overall critical thinking score and its related five sub-scales. These sub-scales encompass analysis, evaluation, inference, deductive reasoning, and inductive reasoning. The analysis, evaluation, and inference sub-scales are based on the conceptualization of the Delphi Report (1990) sponsored by the American Philosophical Association (Facione & Facione, 1994).

The CCTST was chosen for several reasons. Firstly, the instrument is the most current one available. Secondly, the content validity of the CCTST lays in its relationship to the APA Delphi Report Research. The CCTST is the consequence of a conceptualization of critical thinking which rose out of a two-year Delphi research project. The board of specialists associated with the Delphi project included (46) persons active in critical thinking research, education, and assessment. The panel's conceptualization of the critical thinking construct was summarized by Facione. (Jacobs, 1994)

The Kuder-Richardson internal reliability coefficients (KR-20) computed for each of the sections of the divided sample ranged from (0.68 -0.69). According to Facione - cited by (Norris & Ennis, 1989). This is seen as highly acceptable for an instrument where items are expected to discriminate well between individuals, for an instrument that relies on dichotomous scoring and is aimed at testing a broad range of complex constructs.

Frage (2006) adapted and translated the CCTST Form (A) into Arabic language, he removed 9 items after well-documented reliability and validity. The CCTST Form (A) (Arabic version) was adopted and checked to support the appropriateness of its content to the objectives by instructors Ph.D., assistants' professors, and professors in education from many universities in Gaza for the face and content validity.

The test was submitted to them along with a checklist including the following categories:

(i) The question is appropriate to grade level.
(ii) The question's wording is understandable.
(iii) The question's context is appropriate to the Palestinian environment.

Regarding the experts' comments and their responses to the checklist, the question 13,15 and 21 were removed from the test because it was problematic, not understandable, and did not suit students of 11th- grade. All of the questions remained were checked and revised by comparing the Arabic version with the original version to make the wordings clear and suitable for the skill type being measured. All of the questions were modified because the Arabic version has many translation errors. Some of the questions were adapted to appropriate the Palestinian environment and students of 11th- grade like questions 3,9,11,12,14,15,18,23,24.25. For cultural reasons,

Question 19 was adapted by exchange it with question 20 from CCTST form B which measures the same skill. In the pilot study, the Arabic version of the CCTST was administered in the mid of the first semester of the 2019-2020 academic year of which participants (N = 30) enrolled in Secondary Awney hertany school in North Gaza Directorate. The pilot study aimed to check the clarity of the questions, and the adequacy of the test duration. The questions were very clear and take a minimum of (45) minutes to administer. Finally, the CCTST (The Palestinian version), comprises (22) multiple-choice questions. The analysis sub-scale of the CCTST includes three sub-skills: examining ideas, detecting arguments, and analyzing arguments, and measured by questions 4,5,6,7, and 8. The evaluation sub-scale on the CCTST also includes two sub-skills: assessing claims and assessing arguments and measured by questions 1,2,3,16,17,18,19,20,21 and 22. Inference, the third sub-scale also includes three sub-skills: querying evidence, conjecturing alternatives, and drawing conclusions, and measured by questions 9,10,11,12,13,14, and 15.

To test validity and reliability, the CCTST (the Palestinian version) was administered in the same semester of which participants (N = 30) enrolled in Arafat Gifted Secondary School in the West Gaza Directorate. According to data analysis by SPSS 25, CCTST has good reliability, the overall Cronbach alpha reliability calculated for this study was (0.77). This statistic falls within the worthy extents detailed in previous studies. Also, the CCTST has high internal consistency validity because every question has a significant correlation with its subtest. The correlations coefficients of all questions with its subtest are ranged from (0.264) to (0.725).

Test of Logical Thinking (TOLT)

In 1980 Tobin & Capie developed the Test of Logical Thinking (TOLT) commenced with a selection of ten items previously reported by Lawson (1978). The first two items on the TOLT measure proportional reasoning ability. The second two items measured controlling variables. The third two items were designed to measure probabilistic reasoning. The fourth two items measured correlational reasoning, and the last two items on the TOLT measured combinatorial reasoning. (Tobin & Capie, 1981)

The TOLT was chosen for several reasons. First, the instrument is the most current one available. Secondly, Tobin & Capie (1981) gave evidence suggests that the TOLT does measure logical thinking. Thirdly, the high reliability and validity are supportive of an effective group test of formal thought. The test is suitable for students from grade 6 through college.

Many studies used the TOLT like (Janice Guthrie, 1991), the average score for eleventh-grade chemistry students is around (4.5) out, of (10). The reliability of this test ranges from (0.80) to (0.85). The Kuder-Richardson internal reliability coefficients (KR-20) computed by Abo-rman (1991) for the TOLT (the Arabic version) was (0.66) which consider acceptable, she also investigates the TOLT
content-related validity. she removed the ninth and tenth items which measure combinatorial reasoning because it is not measured as other questions. The TOLT (the Arabic version) was used by (Al khawlda, 2008) and (Al-afifi & Ambusaidi, 2014), it has been modified and applied to the Omani environment also by (Al-Hadthrme, 2011), the test and retest reliability was (0.72).

The researchers accredited Abo-rman (1991) adaptation of TOLT, which was checked to support the appropriateness of its content to the objectives by instructors Ph.D., assistants' professors, and professors in education from many universities in Gaza for the face and content validity. The test was submitted to them along with a checklist including the following categories:

(i) The question is appropriate to grade level.
(ii) The question's wording is understandable.
(iii) The question's context is appropriate to the Palestinian environment.

Regarding the experts' comments and their responses to the checklist, some questions and pictures were modified. All of the questions were checked and revised by comparing the Arabic

version with the original version to make the wordings clear and suitable for the skill type being measured.

In the pilot study, the Arabic version of the TOLT was administered in the mid of the first semester of the 2019-2020 academic year of which participants (N = 30) enrolled in Secondary Awney hertany school in North Gaza Directorate. The pilot study aimed to check the clarity of the questions, and the adequacy of the test duration. The questions were very clear and take a minimum of 40 minutes to administer as the time which is given by Tobin & Capie (1981). Finally, the TOLT (The Arabic version), comprises eight items, every two items measure one ability and have (2) scores.

To test validity and reliability, the TOLT (The Arabic version), was administered in the same semester of which participants (N = 34) enrolled in Arafat Gifted Secondary School in West Gaza Directorate. According to data analysis by SPSS 25, TOLT has good reliability, the overall Cronbach alpha reliability calculated for this study was (0.842), this statistic falls within the worthy extents detailed in previous studies. Also, the TOLT has high internal consistency validity because every item has a significant correlation with its subtest. The correlation coefficients of all items with its subtest are ranged from (0.834) to (0.940).

Procedures and Data Analysis

The data collection process regarding physics achievement was gathered based on aggregated data from the school's database of the standardized final physics exam. The total scores of the standardized final physics exam, the CCTST, and the TOLT were (30), (22), and (8) respectively. Both the CCTST and the TOLT were conducted on 11th-graders, they were computer-scored and transferred to the SPSS program in October 2019. The scoring of two tests produced scores for three subscales for the CCTST and four sub-scales for the TOLT as well as an overall score for all of them. According to the instructions provided in the CCTST and the TOLT manual, an unanswered question was established as an incorrect reaction and was had a mark of zero.

Results

In the current study, data were examined by SPSS 25 software, in terms of influential outliers, normality, linearity, and multicollinearity. There are no outliers because the maximum value of Mahalanobis D2 was (9.73) less than the critical value, F (214) = 283.66, p<. 0.001. However, for sample sizes of (200) or more, nonnormal variables' effects may be negligible (Hair et al., 2014). The examination of bivariate scatters plots resulted that variables are linearly related and their variances are homogenously distributed. The analysis of residuals did not exhibit any nonlinear pattern to the residuals, thus ensuring that the overall equation is linear. The histogram analysis of residuals exhibited most of the values under the normal curve, thus indicating the regression results must be generalizable. The variance inflation factor (VIF) ranged from (1.144) to (1.069) (Table 6), therefore, no multicollinearity problem was encountered, as these values less than the critical value of (10).

The participants' Physics Achievement PA, overall CCTST, overall TOLT, and sub-scales statistics are displayed in Table (4). The participants did best on the physics achievement test PA, the poorest on CCTST and their performance on TOLT was less than acceptable. Some participants were able to correctly answer all of the questions of the PA test and TOLT, Conversely, none of them was able to achieve the total score (22) of CCTST. In fact, on the CCTST, the maximum score of (16) was achieved by one participant; (80%) of individuals achieved between (1 to 10). On the TOLT, (15) participants achieved the maximum score of (8), and (52%) of individuals achieved between (zero to 3). On the PA test, (10.2%) of participants achieved the maximum score of (30), and (12.1%) failed in the exam.

Table (4) Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Physics Achievement Test (30)	215	2	30	23.13	6.752
Critical Thinking CCTST (22)	215	1	16	8.16	2.580
Logical Thinking TOLT (8)	215	0	8	3.67	2.281
Evaluation (10)	215	0	9	3.55	1.593
Analysis (5)	215	0	4	1.86	.990
Inference (7)	215	0	7	2.75	1.448
proportional reasoning (2)	215	0	2	1.33	.830
the control of variables (2)	215	0	2	.81	.873
probabilistic reasoning (2)	215	0	2	.62	.799
correlational reasoning (2)	215	0	2	.91	.838

The results of Pearson correlations test showed that Physics Achievement PA was statistically related to the following variables: Inference [r =.251, $p < 0.01$], proportional reasoning [r =.271, $p < 0.01$], the control of variables [r =.237, $p < 0.01$], probabilistic reasoning [r =.303, $p < 0.01$], and correlational reasoning [r =.170, $p < 0.05$], on the other hand, PA has a nonsignificant correlation with the following variables: Evaluation and analysis. These variables were neglected in multiple regression analysis.

To answer the study question **"What is the predictive role of critical thinking skills and logical thinking skills on the physics achievement of 11th-graders?"** The researchers revised the related literature, and the bivariate correlations among dependent and independent variables previously identified, they performed stepwise multiple regression analysis to assess the ability of the five predictors: inference, proportional reasoning, the control of variables, probabilistic reasoning, and correlational reasoning to predict the average scores of physics achievement test PA.

According to the multiple stepwise regression analysis outputs presented in Table (5), the best predictor variable was probabilistic reasoning that made a substantial contribution to the overall model fit, with (9.2 %) of the variation in physics achievement was explained. Proportional reasoning was added to arrive at the second model made a substantial contribution to the overall model fit, with a substantive increase in the (R square) by (3.7 %), and increased (Adjusted R square) while also decreasing the standard error of the estimate. With only the first two variables, (12.8 %) of the variation in physics achievement was explained. An additional variable (inference) was added to arrive at the final model, but this variable, although statistically significant, makes a much smaller contribution. The (R square) increased by (2.8 %). The final regression model with three independent variables (probabilistic reasoning, proportional reasoning, and inference) explained almost (15.7 %) of the variance of physics achievement. The (Adjusted R square) of (0.145) indicated to overfitting of the model and that the results should be generalizable from the perspective of the ratio of (215) observations to (3) variables in the equation (72:1 for the final model). Also, the standard error of the estimate had been reduced to (6.245), which means that at the (95%) confidence level (1.96 * standard error of the estimate), the margin of error for any predicted value of physics achievement can be calculated at (+12.2, -12.2).

Table (5): Stepwise Multiple Regression Analysis Outputs Summary [d]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.303[a]	.092	.087	6.450	.092	21.495	1	213	.000
2	.358[b]	.128	.120	6.334	.037	8.898	1	212	.003
3	.396[c]	.157	.145	6.245	.028	7.101	1	211	.008

a. Predictors: (Constant), Probabilistic Reasoning

b. Predictors: (Constant), Probabilistic Reasoning, Proportional Reasoning

c. Predictors: (Constant), Probabilistic Reasoning, Proportional Reasoning, Inference

d. Dependent Variable: Physics Achievement

According to Hair et al. (2014) table, at alpha level (0.05), and the ideal statistical power level (0.8), the minimum statistical significance for (R square) was (0.12) with (5) predictor variables and (100) of sample size when this size increase to (250), (R square) decrease to (0.05). G* power 3.1.9.4 program was used to calculate the significance (R square), with modified the number of predictor variables into three with (215) of sample size, at alpha level (0.05), and the ideal statistical power level (0.8), the minimum statistically significance for (R square) was (0.029). This critical value indicated that (0.157) of (R square) in the final model was statistically significant and should be generalizable.

The ANOVA analysis provided the statistical test for the overall model fit, the test indicated that the third model with (214) degrees of freedom, was statistically significant with an F ratio of 13.063 and a significance level of (0.000). The result is the joint influence of probabilistic reasoning, proportional reasoning, and inference, on students' achievement in physics is significant.

The results in Table (6) show the regression coefficients (B) and the standardized coefficients (β) reflect the change in the Physics Achievement PA measure for each unit change in the independent variables. By regression coefficients (B), the regression equations of the three models can be formulated, the final model was the best, the unstandardized regression equation is:

Physics Achievement score = 17.799 + (1.742) * Probabilistic Reasoning score
+ (1.519) * Proportional Reasoning score
+ (.813) * Inference score

Probabilistic reasoning had significant influence on physics achievement ($t = 3.050$; $P < 0.01$). The regression coefficient (B=1.742) reflects a (1.742) increase in physics achievement measure, for each unit increase in probabilistic reasoning score, with the (95%) confidence interval of (0.616 to 2.87), which does not include zero, that support the significant influence of probabilistic reasoning on PA.

Proportional reasoning had significant influence on physics achievement ($t = 2.820$; $P < 0.01$). The regression coefficient (B=1.519) reflects a (1.519) increase in physics achievement measure, for each unit increase in proportional reasoning score, with the (95%) confidence interval of. (0.457 to 2.580), which does not include zero, which supports the significant influence of proportional reasoning on PA.

Inference had significant influence on physics achievement ($t = 2.665$; $P < 0.01$). The regression coefficients (B=0.813) reflect a (0.813) increase in physics achievement measure, for each unit increase in inference score, with the (95%) confidence interval of (0.211 to 1.414), which does not include zero, that support the significant influence of inference on PA.

The stepwise procedure highlighted the importance of probabilistic reasoning variable in assessing overall model fit, also the comparison between standardized coefficients (Beta) indicates that probabilistic reasoning was the best predictor with β value of. (0.206), while inference was the least predictor with a β value of (0.174) to physics achievement in the final regression model.

Table (6): The Regression Coefficients (B) And the Standardized Coefficients (β) [a]

Model		Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	21.548	.557		38.704	.000	20.451	22.646		
	Probabilistic Reasoning	2.558	.552	.303	4.636	.000	1.470	3.645	1.000	1.000
2	(Constant)	19.689	.829		23.746	.000	18.054	21.323		
	Probabilistic Reasoning	2.069	.566	.245	3.657	.000	.954	3.185	.916	1.091
	Proportional Reasoning	1.625	.545	.200	2.983	.003	.551	2.699	.916	1.091
3	(Constant)	17.799	1.082		16.447	.000	15.666	19.932		
	Probabilistic Reasoning	1.742	.571	.206	3.050	.003	.616	2.868	.874	1.144
	Proportional Reasoning	1.519	.539	.187	2.820	.005	.457	2.580	.911	1.097
	Inference	.813	.305	.174	2.665	.008	.211	1.414	.935	1.069

a. Dependent Variable: Physics Achievement PA

Discussion

The purpose of this study was to investigate the predictive role of critical thinking skills and logical thinking skills on the physics achievement of 11th-graders. Multiple regression analysis was applied to survey the variables under test. The findings of multiple stepwise regression analysis revealed that the three variables: probabilistic reasoning, proportional reasoning, and inference were significant predictors of physics achievement. (See table 5) These variables explained almost (15.7%) of the variance of physics achievement. This result is practically significant because three variables could not be only contributing to physics achievement. This result means that (84.3%) of the variance in student's achievement in physics can be predicted by other factors, such as other types of thinking skills, gender, learning environment, and instructional strategies. For example, (Mkpanang, 2016) study indicated that (52%) of the total variation in physics achievement was explained by creative style and gender. Another study conducted by Yeo & Chong (2012) revealed the combination of mathematical thinking skills will predict (35.9%) of the variances in physics achievement among the students. Also, (Hung, 2010) study indicated that the inquiry effect on science achievement. Similarly, (Zhang, 2001) study reported that thinking styles contribute to academic achievement.

This study indicated that there is a significant joint influence of probabilistic reasoning, proportional reasoning (as logical thinking skills), and inference (as critical thinking skills), on students' achievement in physics is significant. This result supports the findings of previous studies

(Bitner-Corvin, 1988; Gurcay & Gulbas, 2018; Ramos et al., 2013; Semerci, 2011; Dimitrios Stamovlasis et al., 2010).

Nevertheless, this study's foregoing findings are contrary to (Ramos et al., 2013) study which indicated that the variables evaluation and analysis significantly influence the physics performance of students. The plausible explanation for this contrary can be attributed to that (Ramos et al., 2013) study was applied to university students, also CCTST was not used to measure critical thinking.

Also, these findings partially contradict other findings such as (Bitner-Corvin, 1988) study which revealed that the five logical thinking modes were predictors of academic achievement, but this study reported that the control of variables and correlational reasoning had no significant influence on physics achievement. This contradiction may attribute to Bitner did not use TOLT to measure logical thinking.

Based on the unstandardized regression coefficients (B) (see table 6), this study found that the students who have more scores in probabilistic reasoning by one unit have more scores in physics achievement by (1.742) compared with those students who have less score in probabilistic reasoning. Similarly, the students who have more scores in proportional reasoning by one unit, have more scores in physics achievement by (1.519) compared with those students who have less score in proportional reasoning. Likewise, the students who have more scores in inference by one unit, have more scores in physics achievement by (0.813) compared with those students who have less score in inference.

Based on the standardized regression coefficients (Beta), probabilistic reasoning is the best predictor, while inference was the least predictor of physics achievement.

A possible explanation for these results might be that probabilistic reasoning, proportional reasoning and inference are skills closely connected to physics science, this means that high achieving students might use probabilities, functional relationships, and concluding to understanding concepts, interpret equations, and solving problems. Another possible explanation for these results is that probabilities have been studied since 9th-grade. It may be that high achieving students benefitted from their previous knowledge about probabilities in solving physics problems. These explanations are in agreement with Trifone (2016) who claimed that students lacking probabilistic reasoning or proportional reasoning have difficulty with physics subjects.

This study reported that the control of variables, correlational reasoning, evaluation, and analysis had no significant influence on physics achievement. It is difficult to explain these results, but it might be related to physics discipline, students' abilities, thinking tests, or the predictive power of the three other variables. These results, therefore, need to be interpreted with caution.

Conclusions

In light of the findings of this study, the researchers concluded the following:

1. The joint influence of probabilistic reasoning, proportional reasoning, and inference, on students' achievement in physics, is significant. That is, students who have good skills in probabilistic reasoning, proportional reasoning, and inference, will have good scores in the physics exam of 11th-grade.
2. The evaluation skill has no significant influence on students' achievement in physics. This means that evaluation skill does not have any impact on physics achievement, even the high performing students in physics, are hardly able to perform evaluation skill.
3. The analysis skill has no significant influence on students' achievement in physics. This means that analysis skill does not have any effect on physics achievement
4. The inference skill has a significant influence on students' achievement in physics. This means that students who have higher abilities in inference skill, they will achieve higher

scores in the physics test for the 11th-grade, compared to their peers who have fewer abilities in inference skill.

5. The proportional reasoning skill has a significant influence on students' achievement in physics. This means that students who have higher abilities in proportional reasoning skill, they will achieve higher scores in the physics test for the 11th-grade, compared to their peers who have fewer abilities in proportional reasoning skill.
6. The control of variables skill has no significant influence on students' achievement in physics. This means that students who have higher abilities in control of variables skill will achieve similar scores in the physics test for the 11th-grade, compared to their peers who have fewer abilities in control of variables skill.
7. The probabilistic reasoning skill has a significant influence on students' achievement in physics. This means that students who have higher abilities in probabilistic reasoning skill, they will achieve higher scores in the physics test for the 11th-grade, compared to their peers who have fewer abilities in probabilistic reasoning skills.
8. The correlational reasoning skill has no significant influence on students' achievement in physics. This means that students who have higher abilities in correlational reasoning skill, they will achieve similar scores in the physics test for the 11th-grade, compared to their peers who have fewer abilities in correlational reasoning.

Implications for Practice

Based on the findings of the current study, some ideas for educational interventions are presented for policymakers, curriculum developers, school leaders, and teachers:

First, the findings of this study indicate that the joint influence of probabilistic reasoning, proportional reasoning, and inference, on students' achievement in physics is significant. Accordingly, if the students have good skills in probabilistic reasoning, proportional reasoning, and inference, they will have good scores in the physics exam of 11th-grade.

The point here for policymakers, curriculum developers, and teachers is that probabilistic reasoning, proportional reasoning, and inference, matter not only to predict physics achievement but also to decide how to enhance students' achievement in physics. Furthermore, it should be given high priority when designing and implementing physics curricula. It is highly important to suggest that mental and practical skills should be among the main goals of physics education; and accordingly, a physics curriculum should involve various thinking skills, which enhance students' achievement in physics.

Second, other primary findings from this study show the non-significant influence of evaluation, analysis, control of variables, and correlational reasoning skills on students' achievement in physics. Based on these results, it seems clear that the enrichment physics curriculum by evaluation, analysis, control of variables, and correlational reasoning skills, will not make significant differences between students' scores in physics. This finding would be particularly helpful to guide policies to select thinking skills to develop a physics curriculum.

Implications for Future Research

Based on the findings of the current study, a set of recommendations are presented for researchers:

1. Further examinations may reanalyze the variables included in this study to confirm or contradict the introduced conclusions. Another chance may be to analyze each significant predictor identified in this study. This means, inference, proportional reasoning, and probabilistic reasoning, might be analyzed individually in connection to physics achievement.

2. Investigate the direct and indirect effects of the variables included in this study on physics achievement, by path analysis.
3. Investigate similar variables with other dependent variables such as science achievement, chemistry achievement, and biology achievement, or applied to other educational contexts such as primary schools. It would be interesting to know if the same findings can be got in different dependent variables and different contexts.
4. It would be interesting to involve in future research other types of thinking skills, such as creative thinking, analytical thinking, and scientific thinking could be consistent variables to explain most of the variance of physics achievement, that was miss specified in this study.

Limitations

Although the main results of this study were consistently built up, certain limitations should be considered:

1. Data collection instruments included remove nine questions from the original version of the California Critical Thinking Skills Test (CCTST) by Frage (2006), and remove three questions by the researchers. The Arabic version has inaccurate expressions when comparing it with the original version. Although all questions were modified, it would be desirable the depending of
2. This study on the original version. On the other hand, combinatorial reasoning was removed from the Test of Logical Thinking (TOLT) depending on the Arabic version, this variable could be important in predicting physics achievement.
3. Generalization of the results can be restricted because this study is based on a sample from Gaza by were select conveniently three schools and randomly select two classes from every school, although this study accomplished the statistical power's requirements.
4. A standardized final physics exam might be considered not enough to properly reflect physics achievement.
5. There are some variables such as reflective thinking, creative thinking, and metacognitive thinking that could be important in predicting student achievement in physics. These variables must be identified to analyze them in further research.
6. This study considered analysis, evaluation, and inference, are independent variables, although, the APA Delphi report indicates that the different cognitive skills include in critical thinking do not work as independent or isolated factors but instead in a reliant and interconnected way.
7. Variables such as gender, and student willingness to respond to tests that can influence the relationship between thinking skills and physics achievement could be considered as potential confounder variables that might affect this study's conclusions.

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