

The Effects of Self-efficacy Beliefs and Metacognition on Academic Performance: A Mixed Method Study

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Abstract This study investigated the effect of Self-efficacy Beliefs and Metacognition on Academic Performance among high school students using a mixed method approach. A total of 2,138 form four (12th grade) students participated in the study. The mixed-method study consisted of a quasi-experimental approach and in-depth interviews. Quantitative data were collected from self efficacy questionnaire (SEQ), biology ability test (BAT), genetics problem solving test (GPST) and metacognitive prompting questionnaire (MPQ). Qualitative data were collected using in-depth interviews. Quantitative data were analysed using both descriptive and inferential statistics (hierarchical linear regression and factorial ANOVA). Qualitative data were coded, categorized and reported thematically. Regression analysis indicated that self-efficacy was a strong predictor of academic performance. ANOVA analysis displayed statistically significant differences in metacognition in form of metacognitive prompts between groups. Gender effects were also noted with female students outperforming male students on the genetics problem solving test. Subsequent qualitative data suggested that highly efficacious students did better on the tests than less efficacious students. The metacognitive prompting experience provides a rich environment for the development of metacognitive strategies that can promote problem solving skills among high school students.

Keywords: *self-efficacy, metacognitive prompting, academic performance, self regulation*

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1. Introduction

A major concern in science education is the lack of problem solving skills demonstrated by students. In spite of extensive research in the field of problem solving over the past few decades, there are still important areas that remain largely under-explored. Students' self-efficacy beliefs (SEB) in science and metacognitive monitoring in problem solving situations are two of these areas. This study examined the relationships among self-efficacy, metacognition, and problem solving.

Self-efficacy, defined by [3], as the conviction in one's ability to successfully organize and execute courses of action to meet desired outcomes is one of the most powerful and reliable predictors of problem solving success. Research conducted mostly in Western and European cultures, has established that students who believe that they are capable of adequately completing a task and have more confidence in their ability to do so, typically display the highest levels of academic achievement and also engage in academic behaviours that promote learning [4,48,65]. Most of these studies showed that self-efficacy is especially important in learning difficult subjects, such as biology and other sciences, given that students enter courses with varying levels of fear and anxiety. As concepts in the course become

increasingly complex, self-efficacy becomes a more important variable that influences the potential for student learning. [7] have demonstrated that students' self-efficacy is a strong predictor of their academic performance.

Many researchers assert that high self-efficacy is associated with greater metacognition, including more efficient use of problem solving strategies and management of working time, expending greater effort, and persisting longer to complete a task, particularly in the face of obstacles and adversity [7,40,66]. In addition, high self-efficacy is associated with deeper processing of material [4,44], and has been found to positively predict student content learning and science inquiry skills [52]. Furthermore, students with high self-efficacy tend to use metacognitive strategies to generate successful performance outcomes [6,46]. Schunk & Ertmer, (2000) found that self-efficacy moderates all phases of the self-regulation process, allowing for greater cognitive strategies and self-regulation resulting in science academic achievement. Moreover, [56] reported that highly efficacious students are more likely to use self-regulated learning strategies than low efficacious students.

Learning in a science classroom requires students to be self-regulated and this trait goes hand in hand with self-efficacy and metacognition. Therefore, attention is increasingly being paid to the importance of metacognitive skills in learning [17,18]. The importance

of metacognition for high-quality learning and problem solving is widely accepted [8,9,21] and has led to interest in creating learning experiences conducive to developing its use; such as metacognitive prompting. Research treats metacognition and self-efficacy as theoretically interconnected [15,19]. Yet, there is little empirical research that examines how these variables function together in the actual learning process. Self-efficacy beliefs provide insight into why students choose to engage in a particular task. Metacognition through metacognitive prompting on its own acts as a catalyst to evoke the use of self-regulation strategies, such as understanding the nature of a problem, selecting and monitoring strategy, evaluating outcomes, and revising and sometimes abandoning strategies if deemed unsuccessful [25]. Students would benefit from training in metacognition because it also impacts motivation [35,45,65]. Metacognitive prompts are suggested as an instructional technique for enhancing students' learning [9] and may also be influenced by self-efficacy.

Studies on metacognition have proven that there is a strong correlation between metacognition and problem solving. The students with a higher level of metacognitive skills become successful in problem solving [47]. There exist positive and meaningful increases in the achievement of students using instruction activities towards developing metacognitive skills [31,58,24] stated that the problem solving process requires analyzing the given information about the problem, organizing the information, preparing an action plan and assessing all the operations carried out. These operations performed during the process are skills which constitute the character of metacognition.

A variety of methods for promoting metacognition have been studied, and, although focusing on either awareness or monitoring, they often are described using different terms. For example, such methods include metacognitive cueing [60], reflective prompting [13], questioning [29,30], self-generated inferences [63]; self-monitoring or reflection [27], and self-explanations [10]. Many of these strategies can be grouped within the broader category of metacognitive prompting, which [25] define as "an externally generated stimulus that activates reflective cognition or evokes strategy use with the objective of enhancing learning" (p. 878).

Central to this study was the conceptualization that performance measured as genetics problem solving ability is a product of student's metacognition (through metacognitive prompting) and self-efficacy beliefs. The independent variables were Self-efficacy beliefs (SEB) measured by a Self-Efficacy Questionnaire (SEQ), and Metacognition measured using a Metacognitive Prompting Questionnaire (MPQ). The dependent variable was Genetics Problem Solving Ability (GPSA) measured through a Genetics Problem Solving Test (GPST). In the model, gender and background knowledge (BK) were controlled for. The study was guided by the following questions and hypotheses:

1. *To what extent do high school student self-efficacy beliefs predict problem solving ability?*

H_{o1}: Self-efficacy does not predict genetics problem solving ability

H_{a1}: Self-efficacy predicts genetics problem solving ability

2. *To what extent does metacognitive prompting influence genetics problem solving ability?*

H_{o2}: Metacognitive prompting has no effect on genetics problem solving ability

H_{a2}: MP has an effect on genetics problem solving ability.

2. Materials and Methods

2.1. Research Design

The study used a quasi-experimental mixed-methods [12,57], in which quantitative and qualitative data were collected and analyzed in parallel to answer the same research questions but with complimentary effects [39]. A mixed methods study involves the collection or analysis of both quantitative and qualitative data in a single study in which the data are collected concurrently or sequentially and it involves the integration of the data at one or more stages in the research process [12]. Quasi-experimental design was adopted because randomly assigning participants to experimental and control groups was impossible due to the nature of intact classes. According to [5], it is difficult to ensure equivalence of the experimental and control groups in a school by random assignment of students because classrooms are formed as intact groups that cannot be dismantled for the purpose of a study. Focus group interviews explored beliefs, opinions, attitudes, and thought-processes for a sub-sample of students, using focus group interviews.

2.2. Participants

Participants were drawn from 17 schools located from Western Province of Kenya. The 17 schools were selected by stratified sampling technique. According to [37], proportional stratified sampling means that the sampling fraction is the same for each stratum and the sample size for each stratum will be different. A total of 2,138 form four school students were purposively selected because they were the typical group of students who had been taught genetics, the topic under study. Of these students, 1,063 (49.7%) were males and 1,075 (50.3%) were females, based on the current demographics of the schools.

2.3. Instruments

Empirical data on students' background knowledge in biology; self-efficacy beliefs, metacognitive monitoring, and genetics problem solving ability were collected through various instruments. A self-report questionnaire (SEQ); ability tests (BAT and GPST); and metacognitive prompting questionnaire (MPQ) were used to collect quantitative data.

2.4. Biology Ability Test (BAT)

To determine the students' background knowledge (BK) in biology and genetics, I developed a Biology Ability Test, BAT. The test reflected the types of questions that are typically found on content-based standardized tests and in high school form four textbooks in Kenya. It was a 25-item test with multiple choice question, matching pairs, True/False, and one-word answer questions. It was scored

on a scale of 0 to 30 points, with nearly all the questions being multiple choices.

2.5. Self-efficacy Questionnaire (SEQ)

A Self-efficacy Questionnaire was used to measure students' self-efficacy beliefs about their genetics problem solving ability. This questionnaire is a modified version of the Self-efficacy and metacognitive Learning Orientation Inventory- Science (SEMLI-S) developed by [59] and used in assessing the self-efficacy beliefs of students in science. The SEQ was developed by the researcher by modifying items from three sub-scales of Self-Efficacy and Metacognition Learning Inventory—Science (SEMLI-S) to make it applicable to the study population and relevant to the research questions. SEMLI-S is a valid and reliable tool for investigating high school students' self-perceptions of elements of their metacognition, self-efficacy and science learning processes. Modification of existing assessment instruments and outcome measures is common practice; this frequently occurs to render a measure more closely suited to the specific purposes and environment for which it is intended and such that it answers the specific questions it is intended to answer [28]. According to [28], such adaptations, when relevant to a particular setting, are justifiable insofar as the changes are necessary. This modified version was named Self-efficacy Questionnaire (SEQ) with three sub scales, science self efficacy (SSE), self regulation (SR), and constructivist connectivity (CC). Internal consistency for the modified scale in the current sample was above the acceptable levels: Science self-efficacy, $\alpha=0.873$; Self-regulation, $\alpha=0.922$; Constructivist Connectivity, $\alpha=0.917$; Overall Self-efficacy scale, $\alpha=0.946$. The final instrument had 25 items on a 5-point Likert-type scale: 1 = *Strongly Disagree (SD)*; 2 = *Disagree (D)*; 3 = *Uncertain (UN)*; 4 = *Agree (A)*; and 5 = *Strongly Agree (SA)*

2.6. Genetics Problem Solving Test (GPST)

The 18 item genetics problem solving test was used to collect information on students' knowledge and understanding of genetics concepts and problem solving. The test was developed by drawing questions from past paper exams (KCSE, 2007-2010), from four biology textbooks and revision biology textbooks used in Kenya.

2.7. Metacognitive Prompting Questionnaire (MPQ)

MPQ was a 14-item questionnaire on a Yes/No scale that served as self-metacognitive questioning. The metacognitive prompts were developed with the purpose of connection making, strategy use, reflection and comprehension of the problems to be solved. The 14 items were embedded in the GPST for the experimental group. Besides being used as thought-provoking questions, the responses to the MPQ items were analyzed to provide a measure of students' level of metacognitive monitoring.

2.8. Focus Group Interview Schedule

A series of focus group interviews were conducted one week after the quantitative study. A set of guiding questions was developed prior to the start of the study to

guide the focus groups. The interviews sought to explore participants' experiences during the quantitative study and their perspectives on learning of biology.

2.9. Data Collection Procedures

After giving consent to participate in the study by signing informed consent forms, participants completed a biology background knowledge test followed by a self-report SEQ. Subsequently participants were assigned to either a treatment (MP) or control group (No MP) in their intact classes, before undertaking the genetics-problem solving test (GPST). The participants completed the instruments in the following order and time frame: BAT (30-45 minutes), SEQ (20-25 minutes), Metacognitive prompting questionnaire embedded in GPST for experimental group and the Genetics problem solving test (GPST) alone for control group (60-80 minutes).

Focus group interviews were conducted one week after the quantitative data collection with a sub sample of 48 participants drawn from six schools purposively selected after running the SEQ results. Four top scorers and four bottom scorers on SEQ from each of the six schools ($n = 48$) participated in the interviews.

Validity and reliability of instruments were assessed. Through expert review, content validity of BAT and GPST was conducted. The raters' report for both tests indicated that the tests measured what they purported to measure. SEQ was subjected to exploratory factor analysis (EFA). The purpose of this analysis was to provide an empirical test of the plausibility of the theoretically derived three-factor structure of the modified version of the SEMLI-S, the SEQ. A KMO value of 0.954 ('superb' according to [20]) indicated that the data were highly structured and potentially good for Factor analysis. KMO values for individual variables; a measure of sampling adequacy (MSA) were all greater than the acceptable limit of 0.5 (all were $>.78$). Bartlett's test of Sphericity was statistically significant ($\chi^2(300) = 26106.291, p < 0.001$), an indication that there are some relationships between the variables that were included in the analysis. In summary, all of the tests for adequate assumptions in conducting a factor analysis were more than sufficiently satisfied.

Exploratory factor analysis yielded a three factor solution which accounted for approximately 53% of the variance. Science self-efficacy; SSE (factor 1) accounted for 36.9% of the variance in the original 25 items. The second factor loaded onto items relating students' assessment of self-regulation accounted for 8.4% of the variance. The items which loaded on factor 3 all relate to how students make connections between concepts in the process of learning. This factor; constructivist connectivity accounted for 7.8% of the variance. Therefore the underlying structure of SEQ is three factors (sub-scales) namely: science self-efficacy, self-regulation, and constructivist connectivity.

Cronbach's α , a measure of internal consistency was computed using SPSS Reliability Analysis for each of the predictor variables. The results indicated that reliabilities were acceptable high (Self-efficacy, $\alpha=0.873$; Self-regulation, $\alpha=0.922$; Constructivist Connectivity, $\alpha=0.917$; Overall Self-efficacy scale, $\alpha=0.946$).

2.10. Data Analysis

2.10.1. Quantitative Data

Descriptive analyses were conducted to examine the measures of central tendency (mean) and dispersion (standard deviation) while Pearson’s product moment (zero order) correlation coefficients were computed for the whole sample to determine the relationships among genetics problem solving ability (GPSA), the self-efficacy subscales (i.e., Constructivist Connectivity, Self-regulation, and Science Self-efficacy Beliefs).

To answer research question 1, a sequential hierarchical linear regression analysis was conducted for GPSA outcome variable. To address the second research question, 2 by 2 factorial ANOVA was conducted to determine the main effects and the interaction between gender and metacognitive prompting.

According to [26], a factorial design allows for greater generalizability and a much broader interpretation of the results and at the same time gives researchers the opportunity to say something useful about each of the independent variables (factors) separately.

2.10.2. Qualitative Data

Qualitative data were transcribed verbatim, coded using a combination of theoretical and open coding techniques, then categorized and reported thematically. The open coding process was done using the participants’ own terms and researcher’s interpretation of the meaning of participants’ comments or ideas. Coding started with transcribing the data, coding phrases, and modifying codes into categories [38] that encompassed conceptually similar codes, with the participants voices reflected. Categories are higher order concepts that group codes together based on their ability to describe the phenomenon under investigation [54]. The categories that were related were organized into salient topics/themes. Two main themes emerged; degree of self-confidence and metacognitive monitoring.

3. Results

3.1. Statistical Assumptions

For the regression analysis, the data were assessed for linearity, outliers, multivariate normality, homoscedasticity, 1st order autocorrelations, independence, and multicollinearity. Assumption of linearity was assessed by visual inspection of a matrix scatter plot. The plot indicated positive linear relationships between the predictor variables and the outcome variable hence no violation was indicated [55]. Outliers were identified by examining the standardized Z-scores. Normality of residuals was tested using histograms and normal

probability plot. The histograms for the whole sample and experimental group were both bell-shaped and the observed residuals in the NPP were pretty much distributed around the straight line. The remaining assumptions were assessed a residual plot. The residual points are randomly and evenly dispersed throughout the plot. This pattern is indicative of a situation where the assumption of homoscedasticity is met. There is no direct test for multivariate normality, so I tested each variable individually and assumed that they are multivariate normal if they were individually normal, though this is not necessarily the case. The skewness and kurtosis for all variables tested in this study were within this range hence the assumption of multivariate normality was met. Durbin-Watson statistic was examined to check for 1st order autocorrelations a value of 1.761 indicated that the residuals from a multiple regression are independent. Overall the model appears, in most senses, to be both accurate for the sample and generalizable to the population. Multicollinearity was tested by using Variance Inflation Factor (VIF) and Tolerance values. The VIF values were well below 10 (ranging from 0.046 to 1.986) and the tolerance statistics were all well above 0.20 (ranging from 0.503 to 0.956. Therefore multicollinearity was not a concern for this study.

For ANOVA test normality was checked through standardized skewness and Q-Q plot. The data were statistically normal. Levene’s test was significant thus the assumption of equal variance was violated. An alpha level of .05 was used for the initial analyses. However, Analysis of variance is robust to violations of the assumption of homogeneity of variances provided the ratio of the largest group variance is not more than 3 times the smallest group variance. In the present study, the ratio was 1.095 less than the rule of thumb of 3.0.

3.2. Descriptive Statistics

Means and standard deviations for the dependent measure (GPSA), gender, background knowledge (BK), and self-efficacy (SE, SR, and CC sub-scales) variables are presented in Table 1. The results of the descriptive analyses demonstrated a range of 2 to 40 on the GPSA score (possible range 0-40) and no evidence of ceiling or floor effects ($M = 25.28, SD = 8.376$). The data are thus generally as expected in terms of means and SD’s, and there are no out-of-bounds entries beyond the expected range.

3.3. Correlations

Highlights of the zero-order correlation are presented in Table 1.

Table 1. Means, Standard Deviations, and Intercorrelations for Students’ Genetics Problem Solving Ability and Predictor Variables

Variable	<i>M</i>	<i>SD</i>	<i>N</i>	GPSA	1	2	3	4	5
GPSA	25.28	8.376	2138	1	.739**	.730**	.550**	.456**	.121**
Predictor variable									
1. SSE Subscale	25.80	8.189	2138		1	.671**	.334**	.348**	.046*
2. SR Subscale	27.14	9.200	2138			1	.339**	.371**	.171**
3. CC Subscale	21.18	5.944	2138				1	.266**	.026
4. BK Score	17.38	5.463	2138					1	.116**
5. Gender			2138						1

**Correlation is significant at the 0.01 level (2-tailed)

*Correlation is significant at the 0.05 level (2-tailed)

Significant positive relationships among background knowledge, self-efficacy sub scales, and MP and genetics problem solving ability were revealed. Small significant correlations existed between the predictor variables except SSE and SR sub-scales which showed moderate to high relationship ($r = 0.671$). This correlation is what might be expected in relation to science students' metacognition, self-efficacy and learning processes. We could reasonably expect that students' reporting high levels of science self-efficacy (SSE) might report engaging in high levels of self-regulation and in so doing be more successful science learners. However, according to [20], a correlation of above 0.80 between two predictor variables is an indicator of possible multicollinearity issues. The correlations between the predictors (Gender, BK, SSE, SR, and CC) and the dependent variable, GPSA, were all positive and small to high, ranging from 0.121 (GPSA and Gender) to 0.739 (GPSA and SSE). This indicates that the data are suitably correlated with the dependent variable for examination through multiple linear regressions to be reliably undertaken. Since the correlation between gender

and GPSA was positive and statistically significant ($r = 0.121$, $p = 0.01$), albeit weak, gender was included in the subsequent analyses so as to control for its effects on GPSA and to test its possible interaction with the treatment variable.

4. Primary Results

4.1. Research Question 1

A sequential hierarchical multiple regression analysis was conducted in an effort to test the hypothesis that self-efficacy does not predict students' genetics problem solving ability, as measured on a 20-item genetics problem-solving test (GPST). Gender and background knowledge (BK) in biology were controlled for by being entered in the first block. Science self-efficacy (SSE), Self-regulation (SR), and constructivist connectivity (CC) were entered in block 2. Results are presented in Table 2.

Table 2. Hierarchical Regression Analysis Summary for Predicting Genetics Problem-solving Ability (N = 2138)

Step and Predictor Variable	B	SE B	β	R^2_{Adj}	ΔR^2
Step 1				0.212***	0.213***
Gender	1.166	0.324	0.070***		
BK	0.687	0.030	0.448***		
Step 2				0.733***	0.521***
Gender	0.435	0.191	0.026**		
BK	0.192	0.019	0.125***		
SSE	0.389	0.016	0.380***		
SR	0.300	0.014	0.330***		
CC	0.392	0.017	0.278***		

** $p < 0.05$, *** $p < 0.001$, $R^2 =$ change in ΔR^2

The initial model accounted for 21.2% of the variance in the student's genetics problem-solving ability, ($R^2 = 0.213$, adjusted $R^2 = 0.212$, $p < 0.001$). Both gender and biology background knowledge were significant predictors of the students' ability to solve genetics problems (Table 2). Being significant predictors of genetics problem solving ability, gender and BK were left in the model. The final model was statistically adequate meaning accounting for 73.3 % of the variance of the student's genetics problem-solving ability, ($R^2 = 0.734$, adjusted $R^2 = 0.733$).

The addition of the three predictors in the second (final) model significantly improved the model fit, ($\Delta R^2 = 0.521$, $F_{change}(2, 2134) = 1392.095$, $p < 0.001$). The results show significant positive regression beta weight for SSE ($\beta = 0.380$, $p < 0.001$), an indicator that students with higher levels of science-self efficacy are expected to have higher GPST score, after controlling for the other variables in the model. Likewise, self-regulation ($\beta = 0.330$, $p < 0.001$) and constructivist connectivity ($\beta = 0.278$, $p < 0.001$) were important predictors of genetics problem solving. The beta weights for both gender and BK ($\beta = 0.166$, $p < 0.001$) shrunk although still statistically significant, an indication of overlap or mediation (see Table 2). Science self-efficacy was the strongest predictor of student's genetics problem solving ability. The null hypothesis is rejected in favor of the alternative hypothesis; hence high school student science self-efficacy beliefs significantly predicted their genetics problem solving ability.

4.2. Qualitative Findings

Results from the focus group interview corroborated this finding. Some of the participants who were interviewed expressed high degree of confidence in passing the content tests administered during the study. Quotes from two of the participants; John and Ann support this theme:

John: "I had very good experiences. We had questions we have met in exams. They helped us understand better. They helped us build our skills. The questions came from a topic I enjoy but I don't know if I got everything, but I know I have passed very well. The questions were good".

Ann: "The questionnaires were challenging but not so hard. The hard questions made me go back and revise. I believe I did well. The questions were not very hard. But some of us are over-confident but you end up with shallow answers. You need to think deeply before answering a question".

One of the emergent themes was degree of self-confidence. This theme depicts the level of confidence expressed by the study subjects. The participants seemed confident in what they were or had done. They were sure that they were going to pass the tests. Furthermore, these participants scored highly on SEQ instrument (John = 122/125 and Ann = 125/125) and when their scores on GPST were tracked it showed a positive correlation (John = 34/40 and Ann = 39/40). Two more participants who had low scores on SEQ (Peter = 88/125 and Betty = 70/125) had doubts about their performance in the content tests. They indicated that the tests were difficult and that they

had not prepared for them. They had very low scores on GPST (Peter = 03/40 and Betty = 11/40).

Peter: “Yes, a student having learned for four years without multiple choice questions, you need questions where you give your own answers. In both BAT and GPST I was just reading the answers, they look correct, I was worried. I could not get the correct answer. The tests were challenging due to lack of preparation. There was no time to internalize the facts because we had just completed tackling the topic, hmm, yes it was challenging. I had not studied. I had a lot of problems. I don’t think I will do well in these tests”.

Betty: “Surely madam, the questions were a bit challenging, simple but tricky. They required high thinking capacity especially the first one (BAT). I did not do well but after that I went back to refer to my textbooks because I had not understood. GPST Punnett square was very challenging. Genetics is a problem to me. When the test came I did badly but I went back to revise genetics. Surely I was afraid I may not do well in exam”.

4.3. Research Question 2

To address the second research question, a 2 x 2 Factorial Analysis of Variance was conducted to evaluate the effects of the metacognitive prompting on genetics problem solving ability of female and male participants. The two independent variables in this question are gender (Male and Female) and treatment (No Metacognitive Prompts and Metacognitive Prompts). The dependent variable is the score on the GPST. The means and standard deviations for the GPSA measure as a function of gender and treatment (MP) are presented in Table 3.

Table 3. Means, Standard Deviations and Sample Sizes per Cell of GPSA

	No Metacognitive Prompts	Metacognitive Prompts	Total
Male	23.06 (9.058); N = 521	25.40 (8.577) N = 549	24.26 (8.888) N = 1070
Female	25.20 (7.768) N = 537	27.40 (7.480) N = 531	26.30 (7.701) N = 1068
Total	24.15 (8.492) N = 1058	26.39 (8.114) N = 1080	

Note: Standard Deviations shown in parentheses

Descriptive statistics indicated that on average males scored lower than females in both conditions (no metacognitive prompts and metacognitive prompts). Furthermore, treatment worked regardless of gender.

The results for the 2 x 2 factorial ANOVA are reported in Table 4. There was a non-significant interaction between gender and MP, $F(1, 2135) = 0.043, p = 0.836$.

Table 4. 2 x 2 Analysis of Variance for Genetics problem-solving Ability

Source	Sum of Squares (SS)	df	Mean Square (MS)	F	p-value
Gender	2290.031	1	2290.031	33.712	.000
Treatment	2761.884	1	2761.884	40.658	.000
Gender * Treatment	2.909	1	2.909	.043	.836
Within (Error)	145028.501	2134	67.929		
Total	1516796.000	2138			

Dependent Variable: GPSA whole sample

However, there was a significant main effect for gender, $F(1, 2135) = 33.712, p < 0.001$, and a significant main effect for treatment (MP), $F(1, 2135) = 40.658, p < 0.001$. Gender significantly affected how students solved GPST. Females did better than males on this task, regardless of the condition. MP significantly affected how students solved GPST independent of gender.

The results indicate that males and females were not affected differently by the treatment. In other words, any differences between the treatment groups (No MPs and MPs) were independent upon which gender the subjects were and that any differences between females and males were independent upon which treatment group they were in.

4.4. Effect Size

With significant main effects for MP, Cohen’s d was computed to compare the magnitude of differences between experimental and control groups [11]. Cohen’s guidelines for effect size are as follows: Cohen’s d = 0.20 or less is considered small, Cohen’s d = 0.50 or less is moderate, and Cohen’s d = 0.80 is considered large [11]. The effect size was small to moderate, $d = 0.269$, according to [11] guidelines. This may be due to the fact that the intervention was short-time. Nevertheless, it indicates that there is a difference in the population and these results still draw attention that metacognitive prompts contributed to students’ high ability in genetics problem solving.

4.5. Qualitative Results

Participants in the experimental group who were interviewed indicated that the prompts in the genetics problem solving task provided more than adequate structure for solving the problem. One of the themes generated was Metacognitive Monitoring. The words expressed by the interview participants were a clear indication of their metacognitive monitoring skills. The theme indicates that these students were able to plan, review, and evaluate their work. They are good at monitoring their learning. Pam’s comments attest to this.

Pam: “The test with red questions was tough but those red questions helped me much. I could think for a moment then I remember what we did in class. They were like reminders to me. They really assisted me and I think I will do well in the test. I was scared at first but I got courage when I read the first two and they made me think seriously and reflect on earlier examples we did in class. I thought of different ways to answer some of the questions. Time was not enough but they helped me get organized”.

5. Discussion

Consistent with social cognitive theory, the findings supported the prediction that self-efficacy will have an influence on problem solving accuracy above and beyond biology background knowledge. As has been established by prior research and confirmed with this sample of high school students, self-efficacy is a strong predictor of achievement in science. Of particular concern to science

educators is that failure to take science and mathematics courses because of low self-efficacy can block the pursuit of careers in mathematics and science [63]. In high school students, science self-efficacy correlates with science achievement and is a better predictor of achievement and engagement with science-related activities in and out of the classroom than are gender, ethnicity, and parental background [7,33,40].

Self-regulation was found to predict genetics problem solving ability among high school students in Kenya. Interestingly the importance of self-regulation as a predictor of problem solving did not differ much from that of self-efficacy. This was not surprising though. As [51] have demonstrated, a reciprocal relationship exists between the capacity of self-regulation and the self-efficacy beliefs. As students increase their self-regulation capacity, they increase their self-efficacy beliefs, and vice versa: these self-efficacy beliefs allow the student to face new, self-regulated learning. Self-regulated learners are more self-efficacious for learning than are students with poorer self-regulatory skills; the former believe that they can use their self-regulatory skills to help them learn [45,49,64].

In this study, there was a positive correlation between constructivist connectivity and genetics problem solving ability. Students indicated a high capacity to make connections between their existing knowledge and concepts to the problem solving activities. Contrary to this finding, research has shown that students do not always solve genetics problems correctly because they do not understand important concepts like the relationship between chromosomes, genes, alleles, and characteristics, or the basis of the process of meiosis [2]. When students were interviewed about concepts and topics that are related to genetics, a majority of the participants seemed to know that meiosis, fertilization, blood groups, gamete formation are concepts intricately related to Mendelian genetics. A prompt such as "*Is there any other information that you need to answer this question?*" will demand that a student makes some connection between the question and some underlying concepts. This finding has implications for teachers and curriculum developers. Teachers should aim at conceptual understanding and connections between topics/concepts. Curriculum developers should design curricula that place related concepts in close proximity to help students make connections.

Background knowledge (BK) was found to also predict genetics problem solving ability. Research shows that BK promotes the use of self-regulation strategy due to the availability of cognitive resources and knowledge serving as a basis for evaluation of ongoing performance. This finding is consistent with David Ausubel's theory of meaningful learning. In terms of Ausubel's theory, if students manage to meaningfully incorporate new knowledge into existing knowledge structure (background knowledge), and then we would expect to see relationships between conceptual knowledge after instruction and achievement [1,43]. Indeed, the present study found that background knowledge is a significant predictor of genetics problem solving ability. Although very little research has been documented on gender effects on genetics problem solving ability, this study revealed that gender influences the ability to solve genetics

problems. It necessitated the researcher to further investigate gender effects in this study.

In this study it was expected that adding metacognitive prompting during a problem solving task would result in superior problem solving ability. The results of this study confirmed this expectation that MP influences GPSA. Performance differences between experimental group and the control group lend support to the presumption that MP can compensate for overall deficits when controlling for ability. This finding is consistent with prior studies that have shown prompting results in superior math performance [30,32,47] and problem-solving [25]. Metacognitive prompting is "an externally generated stimulus that either tacitly or explicitly activates reflective cognition or evokes strategy use with the objective of enhancing a learning or problem solving objective" [25]. The present study showed that students with a higher level of metacognitive skills were successful in problem solving regardless of gender.

[25] showed that MP influenced both problem solving accuracy and problem solving efficiency in a math problem solving task. Their findings suggested that under conditions of increasing complexity, metacognitive prompting may induce greater cognitive awareness and the utilization of typically unmindful problem solving strategies. This finding suggests that teachers may include aspects of metacognitive prompts in tests to help students become cognitively aware and use their repertoire of problem solving strategies.

From the interview data it appeared that metacognitive prompts positively affected monitoring and evaluation of the problem space, confirming previous studies [41,42,29,14,22,23,25] that structured guidance through questioning enhances metacognition. [25] found that the judicious use of metacognitive prompting may be a catalyst to help encourage students to use reflective cognition. The qualitative results showed that the question prompts had an effect of directing student attention to important information they might have overlooked, thus facilitating awareness of what is known and not known. Both the quantitative and qualitative findings in this study on the effects of the metacognitive prompts support the hypothesis that metacognitive prompts can facilitate problem solving. The prompts may have implications as a useful classroom tool in guiding students to check their thinking for alignment to problem solving tasks. Furthermore, the use of MPs as an intervention allowed an actual test of the direct impact of MP on problem solving, thus offering a strong case that metacognitive prompts facilitated problem solving.

An interesting finding in this question was that females outperformed the males regardless of whether they belonged to control or experimental group. There is a substantial body of research that documents gender differences in science and it shows that males outperform females on science achievement tests. The differential representation of men and women in the scientific community has been foretold by achievement patterns evident in the elementary and secondary levels. Boys perform better than girls in achievement tests in the typically masculine areas of math and science. The present study has indicated that this is not always the case. Girls outperformed boys regardless of the treatment group. This finding provides a platform for further research

investigating whether females have been misrepresented in previous studies or whether males have been misrepresented in the present study. Some possible questions for further research may be “is the Kenyan school’s curriculum better suited for teaching to both male and female students? Or does it suggest that there is a higher level of interest among females in genetics than in males? Or females have more acuity?” These and many more questions form a fertile ground for further research.

6. Conclusions

Previous studies in self-efficacy and metacognition have already shown that both self-efficacy and metacognition are essential to successful learning. The results of these studies emphasize the importance of students’ self-efficacy and metacognition on performance. The most successful students are those with strong metacognitive skills who manage, monitor and evaluate their performance, and have confidence in their abilities to perform successfully. The findings of the present study showed that both students’ sense of self-efficacy and metacognition influence problem solving. This indicates that these two constructs are closely related to academic performance. The effects found in these two constructs also lend support that promoting metacognitive awareness and the teaching of metacognitive strategies may enhance student performance. In the process of learning, if teachers design tasks to help the students increase their self-efficacy and metacognitive awareness, this increase might have positive effect on their academic performance.

While the sample in this study involved all the form four students enrolled 17 schools in Western Province of Kenya, there is no assumption that the participants of this study are representative of all form four students in the country or else-where. The study should be repeated with different samples from different backgrounds. The effects can also be traced in a longitudinal study.

Nevertheless, these findings lend support to the teaching of metacognitive strategies and increasing self-efficacy to enhance student performance and the learning experience. Providing high school students with opportunities to learn solving problems in genetics with support from metacognitive prompts can enable them to develop more integrated understandings of the mechanisms of Mendelian inheritance. To help students progress from novice to expert problem solver, we must then pay attention to promoting the feedback loop of metacognition that controls behavior in response to monitoring levels of problem solving.

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Statement of Competing Interests

The author has no competing interests.

List of Abbreviations/Acronyms

BAT: Biology Ability Test
 BK: Background Knowledge
 CC: Constructivist Connectivity
 EFA: Exploratory Factor Analysis
 GPSA: Genetics Problem Solving Ability
 GPST: Genetics Problem Solving Test
 MP: Metacognitive Prompting
 MPQ: Metacognitive Prompting Questionnaire
 SEB: Self Efficacy Beliefs
 SEQ: Self Efficacy Questionnaire
 SR: Self Regulation
 SSE: Science Self regulation
 VIF: Variance Inflation Factor

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