

**PREDICTING PROBLEM SOLVING ABILITY FROM METACOGNITION AND  
SELF-EFFICACY BELIEFS ON A CROSS VALIDATED SAMPLE**

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**ABSTRACT:** *Grounded in social cognitive theory of self-efficacy and self-regulation, this study examined the influence of metacognition and self-efficacy beliefs on genetics problem solving ability among high school students in Kenya using a quasi-experimental research design. The study was conducted in Western Province, Kenya. A total of 2,138 high school students were purposively sampled. Data were collected using a Self-efficacy questionnaire, a biology ability test, a genetics problem solving test, and metacognitive prompting questionnaire. Data were analyzed through descriptive statistics, correlations, and multiple regressions. The hypothesized regression model was tested for its stability through cross-validation. Findings revealed that metacognition and self-efficacy significantly predicted genetics problem-solving ability. Furthermore, self-efficacy moderated the relationship between metacognition and genetics problem-solving ability. This study established a foundation for instructional methods for biology teachers and recommendations are made for implementing metacognitive prompting in a problem-based learning environment in high schools and science teacher education programs in Kenya.*

**KEYWORDS:** Metacognition. Problem solving, Prompting, Self efficacy.

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## **INTRODUCTION**

Problem-solving skills are a key component of academic success, particularly in mathematics but more generally in all STEM fields (NCTM, 2000). More generally, problem solving is one of the focus areas of 21<sup>st</sup> century learning (Kay, 2010). Here too self-efficacy plays a large role.

Zimmerman and Campillo (2003) argue that “having knowledge and skill does not produce high-quality problem solving if people lack the self-assurance to use these personal resources” (pp. 240-241), and that such confidence and self-efficacy “are predictive of persistence and effort during problem solving because they assess beliefs about personal competence and value” (pp. 241-22). In addition, more self-efficacious people display more effort and persistence (Bandura, 1997; Zimmerman, 2000). Bandura (1995) defines self-efficacy as “the belief in one’s capabilities to organize and execute the courses of action required to manage prospective situations” (p. 2). Extensive research has been done on self-efficacy and consistent findings have shown an important correlation between self-efficacy and student achievement (Bandura, 1997; Liu, Hsieh, Cho and Schallert, 2006) and mathematics achievement (Stevens, Olivárez, Lan, & Tallent-Runnels, 2004). Bandura (2001) found that students' perceived efficacy is the main determinant of their perceived professional self-efficacy and career choices. Past research has shown that self-efficacy is positively related with academic performance (example: Amil, 2000; Bandura, 1997; Jones et al., 2011; Jones et al. 2010; Liem et al., 2008; Loo & Choy, 2013; Pampaka et al., 2011; Purzer, 2011 ). Students with a better sense of self-efficacy will achieve better academic performance.

Lack of problem solving skills among students has been a major concern in science education. Extensive research in this field has been done over the past few decades. However, there still remains areas underexplored. Student self-efficacy beliefs is one such area. Self-efficacy, defined by Bandura (1986), 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 (Bandura, 1997; Schunk, 1991; Zusho, Pintrich, & Coppola, 2003). A common finding in these studies is 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. Furthermore, Britner, S., & Pajares, F., (2006) have demonstrated that students’ self-efficacy is a strong predictor of their academic performance.

More research shows that high self-efficacy is associated with greater self-regulation, 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 (Britner & Pajares, 2006; Pajares, 2005; Zimmerman, 2000 ). In addition, students with high self-efficacy tend to use metacognitive strategies to generate successful performance outcomes (Braten, Samuelstuen, & Stromso, 2004; Kitsantas, 2000; Pintrich & De Groot, 1990). 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, Tanner & Jones, (2003) 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 (Efklides, 2008, 2009). The importance of metacognition for high-quality learning and problem solving is widely accepted (Brown, 1978; Carr, 2010; Flavell, 1979) and has led to interest in creating learning experiences conducive to developing its use; such as metacognitive prompting, which Hoffman and Spatariu (2008) define as “an externally generated stimulus that activates reflective cognition or evokes strategy use with the objective of enhancing learning” (p. 878).

The purpose of metacognitive prompting is to guide learners in the process of identifying the structure of problems, creating connections with prior knowledge, and selecting learning strategies (Mevarech & Kramarski, 1997). It is meant to promote learners' regulation of their knowledge and skills during training (Cuevas, Fiore, Bowers, & Salas, 2004) rather than awareness of performance alone. For example, Cuevas et al. (2004) found that incorporating queries into computer-based training can improve integration and application of task-relevant knowledge and led to more accurate comprehension monitoring (Cuevas, 2005). Halpern (2003) argues that in order to improve students' metacognitive monitoring skills, teachers must make these skills explicit so that they can be examined and feedback can be given about how well they are functioning. In the context of problem solving, students can be asked the following questions before they begin a task: “What do you already know about this problem?” “What is the goal or reason for engaging in extended and careful thought about this problem?” “How difficult do you think it will be to solve the problem?” “How will you know when you have achieved the goal?” As students work on a problem, they should be asked to assess their progress, and when the task is completed, to be asked how well the problem was solved and what they learned from solving it. By so doing, students will develop self-assessment skills i.e., the ability and tendency of students to evaluate correctly their knowledge level.

Kapa (2007) examined the effect of various types of training in metacognitive support mechanism on the students' performance on structured (near transfer) and open-ended (far transfer) problems in a computerized metacognitive environment. Different experimental groups received training either during problem solving phases or only after the conclusion of problem solving process. Metacognitive training on both the process and the product phases significantly affected performance on near and far transfer problems in the experimental groups as compared to the control group. Self-instruction helps children to determine and manage previously used problem solving strategies while working on a problem. Through the introduction of internal dialogues, self-questioning enables them to systematically analyze the given information about the problem and manage appropriate cognitive skills. Self-monitoring allows students to monitor their own general performances during problem solving operations and be sure about the appropriateness of the method they use. Thus, metacognition is important to regulate and improve their cognitive tactics and strategies used in problem solving process. The students with a higher level of metacognitive skills become successful in problem solving (Desoete, 2008; Hollingworth & McLoughlin, 2005; Lucangeli, Galderisi, & Cornoldi, 1995; Schoenfeld, 1985)

It can thus be summed from the preceding literature that first, MP promotes problem solving success, but research shows that the differential impact is predicated upon both the availability and willingness to use strategies (DeCorte, Verschaffel, & Op 'T Eynde, 2000; Kramarski & Gutman, 2006; Mevarech & Kramarski, 1997; Schoenfeld, 1985; Veenman, Prins, & Elshout, 2002). Secondly, ability and ability beliefs influence the receptivity to prompting (Bandura, 1997; Braten et al., 2004; Butler & Winne, 1995; Kitsantas, 2000; Pintrich & De Groot, 1990). Precise determination as to the role of self-efficacy and strategy provoked by MP necessitates controlling for background because highly efficacious individuals should have more resources to devote to the strategies induced by MP, although MP should result in more time and effort devoted to monitoring, and impact efficiency (Butler & Winne, 1995).

Thus, our goal was to examine whether self-efficacy beliefs and MP enhanced problem solving ability, when controlling for biology background knowledge. An interaction between self-efficacy and prompting will support the assumption that MP can externalize strategy use and work in conjunction with the expectation of problem-solving success

### **Justification for Scope of Study**

This study investigated the predictive power of self-efficacy and metacognition on genetics problem solving ability among high school students in Kenya. The relevance of developing problem solving skills, metacognitive skills and self confidence among students is of great importance to biology students. In particular, it is acquiring problem solving skills in genetics to be able to deal with emerging issues in this field. Problem solving continues to be an area of concern to science educators, yet much dreaded by students.

Most of the studies reviewed in this paper are confined to foreign/Western countries, particularly America and yet factors said to impact self-efficacy are different and context-specific (Bandura, 1977). Furthermore, self-efficacy and metacognition have been examined in broad areas such as science or subject areas such as mathematics, physics and chemistry but adequate research has not yet established a firm connection between these constructs in a task-specific manner and in an African context. This study sought to address these gaps by investigating a task-specific context of genetics problem solving because research has shown that self-efficacy is task-specific. The researchers thus confined themselves to the metacognitive component of self-regulation by using metacognitive prompts as a treatment variable to examine its unique and interaction effects with self-efficacy beliefs on genetics problem solving, in Kenya.

### **THEORETICAL UNDERPINNING**

The overarching theory for this study was Albert Bandura's socio-cognitive theory of self-efficacy and self-regulation. Social Cognitive Theory (SCT), developed by Bandura (1986, 2001, 2005) and extended by others (Pajares & Schunk, 2001; Pintrich, 2003), explains human learning and motivation in terms of reciprocal interactions involving personal characteristics such as, intrinsic motivation, self-efficacy, and self-determination environmental contexts (e.g., high school), and behavior such as enrolling in college science courses (Bandura, 1986, 1997).

Within this framework, self-efficacy affects one's behaviors and the environments with which one interacts, and is influenced by one's actions and conditions in the environment; what Bandura referred to as "Reciprocal Determinism" whereby human functioning is viewed as a series of reciprocal interactions among personal factors, behaviors, and environmental events. From this perspective, students are capable of influencing their own motivation and performance. In a classroom environment, teachers may require devising instructional methods that promote a healthy learning environment so that students' self-efficacy can be promoted and in turn, academic achievement is enhanced. Compared with learners who doubt their capabilities, those who feel self-efficacious about learning or performing a task competently are apt to participate more readily, work harder, persist longer when they encounter difficulties, and achieve at higher levels (Bandura, 2003).

According to Bandura (1977), self-efficacy beliefs are context-specific evaluations of the capability to successfully complete a task. Self-efficacy beliefs are formed through mastery experiences, vicarious experiences, verbal/social persuasion, and interpretations of physiological and emotional states. Bandura (1986) cautioned that, because judgments of self-efficacy are task specific, different ways of assessing confidence will differently correspond to the assessed performance. Self-efficacy must be specifically rather than globally assessed, must correspond directly to the criterial performance task, and must be measured as closely as possible in time to that task.

Regarding teaching and learning in school, it is important to acknowledge that an individual's self-efficacy beliefs are context bound. A student may have high self-efficacy with respect to knowledge and skills in a particular school subject, but low self-efficacy in another subject. This point is significant to biology educators because biology education has the potential to provide students with a learning environment that differs significantly from other school subjects such as mathematics or history. This includes, for example, engaging students in subjects that concern their daily life and hands-on based learning. Therefore, biology education, in particular the topic of genetics, provides tools for fostering students' self-efficacy beliefs that are less common in other areas learned at school. Research shows that self-efficacy beliefs affect the students' academic successes (Chen, 2003; Pajares & Miller, 1994; Usher, 2009), their choices of the area in which they want to study and their job selections (Waller, 2006) and their choices are related to different motivational beliefs (Chen, 2003; Schnulz, 2005). 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 (Kitsantas & Zimmerman, 2009; Pintrich & De Groot, 1990; Pintrich & Schunk, 1996, 2002) and also engage in academic behaviors that promote learning (Bandura, 1997; Schunk, 1991; Zusho, et al., 2003).

Self-efficacy theory has been applied in science and mathematics. For example, Lent, Lopez, and Bieschke (1991) explored the relation of the four hypothesized sources of efficacy information namely, personal performance accomplishments, vicarious learning, social persuasion, and emotional arousal, to mathematics self-efficacy beliefs. They further studied the relationship among self-efficacy, outcome expectations, interest in mathematics-related college courses, and choice of science-based careers. Results revealed that as predicted by self-efficacy theory, performance experience was the primary source of math self-efficacy, exposure to math-

competent role models promoted choices of math-related careers, and students with low math-anxiety were more likely to feel more confident about their capabilities.

Similarly, Post, Stewart, and Smith (1991) showed that self-efficacy was related to consideration of mathematics and science careers among African American freshmen. Self-efficacy may especially be 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 such that as students accomplish competence in the intended outcomes for the course, their own self-efficacy increases. Subsequently, as self-efficacy increases, students are more willing to undertake more complex tasks and think about more complex ideas (Zimmerman, 2000; Schunk, 2008). Evidence of the predictive power of self-efficacy has been demonstrated in cognitive studies such as mathematics achievement and other learning activities (Zimmerman and Cleary, 2006). In Pampaka et al., 2011 study, of college students, mathematics self-efficacy (MSE), a positive relationship between students' mathematics attainment and their self-efficacy as well as performance at the end of the course was revealed. Since self-efficacy has significant influence on self-regulated learning processes, such as self-observation, self-judgment and self-reaction (Dembo, 2000; Kitsantas & Zimmerman, 2009; Pintrish & Schunk, 1996, 2002; Schunk, 1990, 1994, 1996, 2001), in this study we investigated how self-efficacy beliefs of students are linked in important ways to the use of learning and self-regulatory strategies through the use of metacognitive prompting. This was done in a task-specific context of genetics problem solving because research has shown that self-efficacy is task-specific.

## METHODOLOGY

### Research Design

This study adopted a quasi-experimental static group comparison design grounded in Social Cognitive Theory (SCT) of self-efficacy and self-regulation to examine the influence of high school students' metacognition and self-efficacy beliefs on genetics problem solving ability.

Quasi-experimental design was appropriate to this study because of the static nature of classes in Kenyan schools which does not allow for random assignment of students.

The research question investigated was:

*Does students' metacognition interact with their self-efficacy beliefs to influence genetics problem solving ability*

### Participants

A total of  $N = 2,138$  form four high school students was selected purposively because genetics is taught at form four level (grade 12). The sample comprised of  $n = 1,063$  (49.7%) males and  $n = 1,075$  (50.3%) females, based on the current demographics of the schools. Since the focus of the research question was to investigate the unique and interactive effects of metacognitive prompting and self-efficacy beliefs on genetics problem-solving ability, a sub-sample of  $n =$

1,079 was used to address this research question. This is a group of students in the experimental group who were exposed to metacognitive prompts.

### **Instruments**

In addition to providing individual demographic information, students in the study completed three assessments during the course of this study.

The Biology Ability Test (BAT) was a 25-item test of general knowledge for biology. The BAT was completed at the beginning of the study and was used as a pretest measure of background knowledge in the domain of biology. The purpose of this test was to examine the utility of background knowledge as a covariate in the primary analyses. The items for this test were created for this test and validated by expert reviewers who critically assessed the content of the instrument and rated the items on the following rating scale:

1= Not relevant, 2 = Relevant, 3 = Highly Relevant.

The rater's review showed that all items on BAT were relevant and good enough to be administered to form four students. The average rating ranged from a score of 2(relevant) to 3 (highly relevant). The overall mean rating was 2.56 on a scale of 1 to 3.

The Genetics Problem Solving Test (GPST) was an 18-item classroom assessment focused on solving problems from the domain of genetics. The questions fit within HS-LS3 in the NGSS (National Research Council, 2013). Both face and content validity were achieved through expert review using same experts as those for BAT. The rater's report for GPST indicated that the items were rated relevant, with the mean rating ranging from 2 (relevant) to 3 (highly relevant).The overall mean rating was 2.83 on a scale of 1 to 3. There were two forms of the GPST, which served as the intervention under investigation in this study. The Metacognitive Prompting Questionnaire (MPQ) is a 14-item survey with reliability co-efficient of 0.78. The 14 items were embedded in the GPST for experimental group; serving as an intervention. Details of MPQ are found in the next section.

### **Metacognitive Prompting Intervention**

The experimental or metacognitive prompting (MP) group received a version of the 18-item test with 14 metacognitive prompts embedded within the assessment. The MPs served as an intervention. The control group received the GPST without any metacognitive prompts embedded.

The metacognitive prompts, included comprehension questions, strategic questions, reflection, and connection questions, to be completed during the problem solving tests. Two comprehension questions were designed to encourage students to reflect on a problem before solving it. Four strategic questions were designed to encourage students to think about what strategy might be appropriate for the given problem and to provide a reason or rationale for that strategy choice. Four reflection questions were designed to foster self-monitoring, self-explaining, and self-evaluation in the problem solving process. Finally, four connection questions were designed to encourage students to identify and recognize deep-structure problem attributes so that they could activate relevant strategy and background knowledge. Item analysis was run and results showed that removal of any question would result in a lower Cronbach's alpha. Therefore, no item was

removed from the scale. However in terms of performance for the different types of MP, strategic MPs tended to perform better than the rest with a cronbach's alpha of 0.76, followed by reflection MPs with an overall alpha of 0.74, then comprehension with alpha of 0.72 and finally connection MPs with alpha of 0.69. Overall items 1 and 10 had low item-total correlations, and their deletion would increase alpha. However the increase in alpha was not substantial hence the items were retained.

### **Data Analysis Procedure**

A regression model was hypothesized for this study. To validate the analysis of the conceptualized regression model, cross-validation was conducted by randomly splitting the data into two samples; Training sample (50%) and Cross-validation sample (50%), using SPSS. The 1<sup>st</sup> half, the Training sample (N = 541), was used to generate my hypothesized regression model, whose equation was used to predict values on the remaining half; the Cross-validation (CV) set (N = 538). Descriptive statistics were assessed to check how similar the two samples were.

A sequential hierarchical multiple linear regression was run on the training sample by entering the predictors (centered) in block 2 and the interaction term in block 3 while controlling for background knowledge (BK) in block 1 to test whether including the interaction term increases the variance accounted for in genetics problem solving ability, above and beyond SE and MP. Background knowledge was selected and entered in the first block based on its possible association with problem solving ability shown in previous studies (Nietfeld & Schraw, 2002; Kramarski & Gutman, 2006); so as to control for its effects and see how other predictors contributed above and beyond BK. Based upon the research hypothesis, an interaction term was created by mean-centering SE and MP to get the cross-product  $C\_SE * C\_MP$ ; so as to control for collinearity issues. Mean centering technique changes the scale so that the mean is zero and thus reduces collinearity in the moderated multiple regression model as well making it easier to interpret the model. All statistical assumptions were tested and reported in the next section.

To test for the stability of our model, we correlated the values predicted on my CV sample with the actual GPSA values and used the multiple R value to compute the adjusted  $R^2$ . To compare the consistency of the regression coefficients, we re-ran the analysis on the CV sample and compared the regression coefficients and other important statistics.

## **PRELIMINARY RESULTS**

### **Statistical Assumptions**

The data were checked to assess if the statistical assumptions for scale of measurement, linearity, outliers, multivariate normality, homoscedasticity, independent errors, and multicollinearity were met.

Scale of measurement assumption was met because the data were continuous (ratio scale). Assumption of linearity was assessed using a bivariate matrix scatter plot (Appendix A). The plot indicated positive linear relationships between the predictor variables and the outcome variable with an oval-shaped depiction of points around the regression line (Tabachnick & Fidell, 2007). The remaining assumptions were assessed after running the multiple regression analysis with GPSA as dependent variable and plotting residual plot. Normality of residuals was tested by



NPP (Appendix B) which indicated that residuals are normally distributed. A residual plot (Appendix C) was inspected for homoscedasticity, and independence of residuals. The residual points were randomly and evenly dispersed throughout the plot. This pattern is indicative of a situation where the assumption of homoscedasticity is met. There was no consistent pattern identified in the residual plot, hence the assumption of independent errors is deemed tenable (Field, 2009). To check for 1<sup>st</sup> order autocorrelations, Durbin-Watson statistic was requested for. Values less than 1 and greater than 3 are worrisome, but the closer the value is to 2 the better. The Durbin-Watson value was 1.626 which is so close to 2 (nearest 1 significant figure) that the assumption is met. Assumption of multicollinearity was tested using collinearity diagnostics (Variance Inflation Factor (VIF) and Tolerance values). Specifically, VIF values greater than 10 and Tolerance values below 0.10 indicate multicollinearity in the data (Field, 2009). Based on these criteria, no multicollinearity among the variables of interest was indicated. The VIF values were well below 10 and the tolerance statistics all well above 0.75 (Appendix F). Overall the model appears, in most senses, to be accurate for the sample.

### Descriptive Statistics

Summary of descriptive statistics for Training and CV samples are reported in Table 1. The two samples are pretty much similar on all variables of interest. Gender representation for both samples is reported in Table 1.

**Table 1. Means, Standard Deviations and Comparisons by Gender for Training and CV samples**

	Training Sample			CV Sample		
	N	Mean	Std. Deviation	N	Mean	Std. Dev
GPSA Exptal	542	21.40	9.281	538	21.46	9.254
BK	1093	17.42	5.363	1045	17.35	5.557
C-MP	541	.00235	3.186	538	-.0114	3.136
C- SE	542	1.641	18.411	538	2.799	18.398
C-MP*C-SE	541	24.006	61.509	538	24.085	62.642
Valid N (listwise)	541			538		
Gender	N	% of Total N		N	% of Total N	
Male	276	51.0%		256	49.3%	
Female	265	48.9%		282	52.4%	
Total	541	100.0%		538	100.0%	

The two samples are comparable based on gender. Each sample has approximately equal number of males to females. The results of the descriptive analyses on Training sample demonstrated a range of 2 to 40 (Table 1) on the GPSA score (possible range 0 – 40) and no evidence of ceiling or floor effects ( $M = 21.40$ ,  $SD = 9.281$ ). Means and standard deviations for the dependent measure (GPSA) and for background knowledge, SE and MP variables are presented in Table 2.

### Correlations

Zero-order correlations were conducted and are presented in Table 2.

**Table 2. Means, Standard Deviations, and Intercorrelations for Students' Genetics Problem Solving Ability (GPSA) and Predictor Variables**

Variable	<i>M</i>	<i>SD</i>	<i>N</i>	GPSA	1	2	3	4
GPSA	21.40	9.281	542	1	.425**	.765**	.443**	0.158
<u>Predictor Variables</u>								
1. BK	17.42	5.363	1093		1	.414**	.417**	0.093
2. C_MP	0.00235	3.186	541			1	.410**	0.091
3. C_SE	1.641	18.411	542				1	0.004
4. C_PM*C_SE	24.006	61.509	541					1

\*\*=significant correlations

Highlights of the Zero-order correlation table revealed a significant positive relationship between background knowledge, self-efficacy, and metacognitive prompting and genetics problem-solving ability indicating that students with higher scores on these variables tend to have higher genetics problem-solving ability. Small significant correlations existed between the predictor variables but were not worrisome. Based on this and supported more by theory, metacognitive prompting will be the strongest predictor.

### PRIMARY RESULTS

Results in Table 3 showed that the BK explained approximately 17.8% of total variance in GPSA ( $F [1, 539] = 117.998, p < 0.001$ ). Being a significant predictor in block one ( $\beta = 0.424, p < 0.001$ ), it was kept in the final model because model estimates more accurately reflect population values when conceptually important covariates are retained.

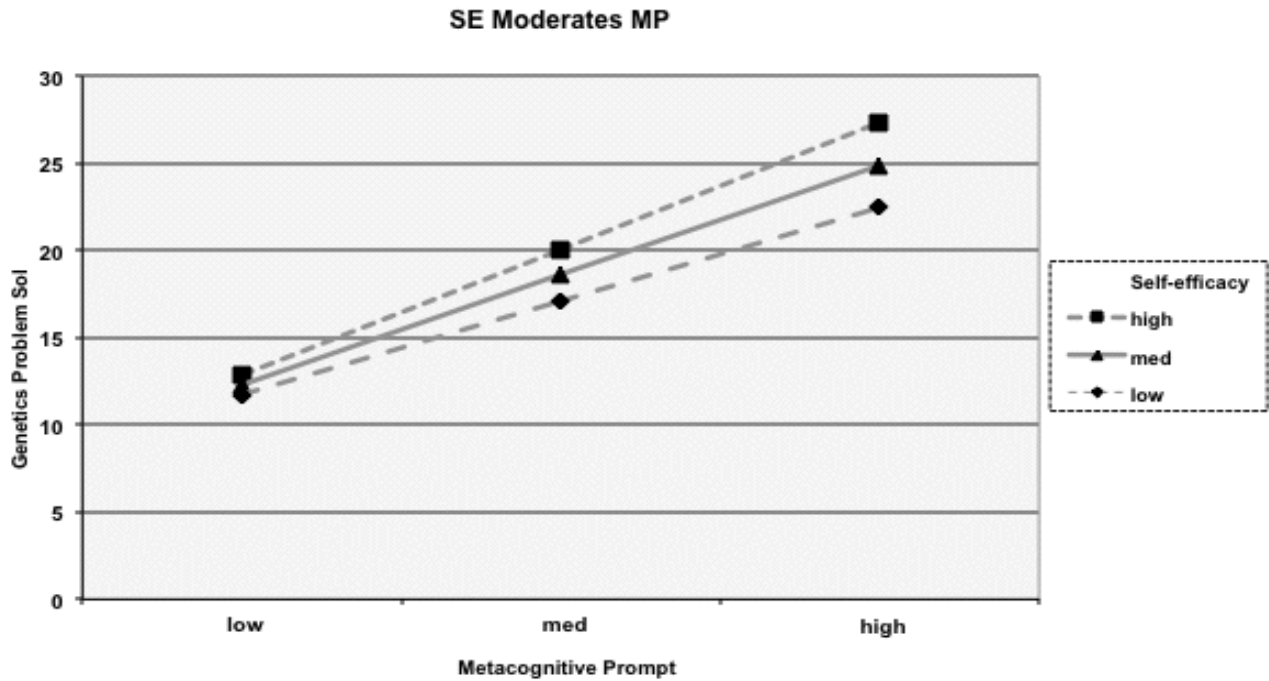
**Table 3. Hierarchical Regression Analysis Predicting Genetics Problem-solving Ability from Background Knowledge, Metacognitive Prompting, and Self-efficacy Beliefs (N = 542)**

Step and Predictor Variable	<i>B</i>	<i>SE B</i>	$\beta$	Adj <i>R</i> <sup>2</sup>	$\Delta R^2$	<i>p</i>
Block 1				0.178	0.180	0.000
BK	0.721	0.066	0.424			0.000
Block 2				0.609	0.432	0.000
BK	0.154	0.053	0.091			0.004
C- MP	1.965	0.090	0.674			0.000
C-SE	0.065	0.016	0.129			0.000
Block 3				0.616	0.008	0.001
BK	0.141	0.052	0.083			0.007
C-MP	1.944	0.089	0.667			0.000
C-SE	0.068	0.015	0.135			0.000
C-MP*C-SE	0.013	0.004	0.089			0.001

Note: BK = Background knowledge, cMP = centered MP, cSE\* = centered SE,  $p < 0.05$  (2-tailed test)

The 3<sup>rd</sup> block (with interaction term) was a significant model [ $F(4,536) = 217.769, p < 0.001$ ] accounted for 61.6% of variance in genetics problem-solving ability. However the  $R^2$  change was small although statistically significant ( $R^2_{ch} = 0.008, p < 0.001$ ).

All predictors were statistically significant, with MP being the most important predictor ( $\beta = .667, t = 21.765, p < 0.001$ ), after controlling for all the variance accounted for by the other three predictors. Metacognitive prompting enhanced performance in the genetics problem solving test. Self-efficacy was also statistically significant as a predictor ( $\beta = 0.135, t = 4.403, p < 0.001$ ). Students with high self-efficacy are better at solving genetics problems. Background knowledge also significantly predicted genetics problem-solving ability ( $\beta = 0.083, t = 2.691, p < 0.007$ ). Adequate previous knowledge (background knowledge) enhances problem solving ability. The interaction term was statistically significant ( $\beta = 0.089, t = 3.315, p < 0.001$ ). The null hypothesis was rejected. The positive regression slope for the interaction term indicates that as self-efficacy increases, the impact of MP on GPSA also increases.



**Figure 1. Simple Slopes Showing Interaction.**

The relationship between metacognitive prompting and genetics problem solving is more important for students with high self-efficacy than for students with moderate and low self-efficacy. MP improves GPSA under conditions of high SE. Notice that the “spread” effect is not dramatic; the huge sample size allowed me to find this subtle effect (Figure 1).. Because the interaction term was statistically significant, simple slope tests were conducted to test whether the simple slopes differ from zero (Aiken & West, 1991; Preacher, Curran, & Bauer, 2006). Results are reported in Table 4. Each of the simple slopes tests revealed a significant positive association between MP and GPSA, but MP was more strongly related to GPSA for high levels of SE ( $\beta = 0.770, t = 28.817, p < 0.001$ ) than for low levels of SE ( $\beta = 0.573, t = 19.626, p < 0.001$ ). For those with particularly high SE, increased use of MP “brings out their best in problem solving tasks.

**Table 4. Summary of Simple Slopes Test**

Low SE		High SE	
Model	Std Coeff.	Model	Std. Coeff.
	Beta <i>t</i>		Beta <i>t</i>
(Constant)	65.726**	(Constant)	87.391**

Centered MP	.573	19.626**	Centered MP	0.770**	28.817**
BelSE	.171	8.049**	AbvSE	0.171**	8.049**
BelInt	.150	5.400**	AbvInt	0.137**	5.400**

Note: \*\*P < 0.001

The MP to GPSA relationship is strongest in the case of high SE and weakest in the case of low SE” as shown by the maximum dispersal of means under conditions of high SE.

The prediction equation derived from the training sample was:

$$\text{Predicted GPSA} = 20.911 + (2.013) * (\text{MP\_C}) + (0.081) * (\text{SE\_C}) + (0.014) * (\text{MP\_C\_SE\_C})$$

Using this equation, GPST values for cross-validated sample were predicted and a Pearson’s Correlation analysis showed that the relationship between the predicted and actual GPST was positive and strong ( $R = 0.764$ ; hence  $R^2 = 0.764$ ). Using this value adjusted  $R^2$  was computed as shown below.

$$\text{Predicted GPSA} = 20.911 + (2.013) * (\text{MP\_C}) + (0.081) * (\text{SE\_C}) + (0.014) * (\text{MP\_C\_SE\_C})$$

$$R = 0.764$$

$$R^2 = (0.764)^2 = 0.5837$$

$$\text{Adjusted } R^2 = \{0.5837 - 3/538 - 1\} / \{538 - 1/538 - 3 - 1\} = \{0.5837 - 0.0055866\} / \{1.00562\} = 0.5781134 * 1.00562 = 0.58136 = 0.581$$

Comparing the adjusted  $R^2$  to that from training set, the shrinkage was  $0.616 - 0.581 = 0.035$ . This shrinkage is minimal; hence the prediction model is stable. Consistency of the regression coefficients was assessed by re-running the regression on CV sample. Results are reported in Table 5.

**Table 5. Summary of Regression Results Comparing Training and Cross-Validation Samples**

Predictors	Training Sample					Cross-Validation Sample				
	<i>B</i>	$R^2$	Adj $R^2$	SEE	Beta wts	<i>B</i>	$R^2$	Adj $R^2$	SEE	Beta wts
Constant	18.39					18.41				
BK	.141				.083	.136				.082
C-MP	1.944				.667	1.845				.625
C-SE	.068				.135	.077				.153
C-MP*C-SE	.013	0.619	0.616	5.75	.089	.016	0.59	0.586	5.95	.108

Predictors: BK, Centered MP, Centered SE, Interaction Term

Dependent Variable: GPSA

The beta weights maintained their positive direction, with slight, negligible differences. The order of predictor importance remained unchanged with MP still the most important predictor. The prediction error in Training set ( $SEE = 5.751$ ) does not differ much from that of CV set ( $SEE = 5.953$ ), providing more evidence that the prediction model is stable and can be applied to different samples from the same population without losing the accuracy of the prediction.

## DISCUSSION

The purpose of this study was to investigate the unique and interactive influences of students' self-efficacy beliefs and metacognitive prompting on genetics problem-solving ability, in Kenya. A significant interaction between MP and SE ( $t = 3.315$ ,  $p = 0.001$ ) was found. All the predictors (BK, C\_SE, C\_MP, and C\_SE\*C\_MP) were positive and statistically significant. C\_MP was the most important predictor followed by C\_SE, then BK and the interaction term in that order. Students solve more genetics problems when they are exposed to metacognitive prompting. Inspection of the simple plots showed a steeper slope for high self-efficacy. The results indicate that the relationship between MP and GPSA changes as a function of the level of self-efficacy (the moderator variable). The findings suggest that under conditions of increasing self-efficacy, metacognitive prompting may induce greater cognitive awareness and the utilization of problem-solving strategies among high school students in Kenya. However, the interaction effect was weak and more research is needed to further investigate this finding.

Findings of significant main effects are consistent with previous research that supported socio-cognitive theory which states that adaptive motivational beliefs such as self-efficacy and attributions to metacognitive strategy use are related to more problem solving and contribute unique variance above and beyond background knowledge (Bandura, 1997; Butler & Winne, 1995; Pintrich, 2000; Pintrich & De Groot, 1990; Linnenbrink & Pintrich, 2003). The findings lend support to the importance of both strategy and beliefs in genetics problem solving ability presumably by motivating the problem solver in positive ways. The finding that for students with high self-efficacy, increased metacognitive monitoring enhanced genetics problem solving ability is consistent with empirical evidence which has shown that high efficacious students, who believe that their course work is interesting, important and useful, are more likely to engage in various cognitive and metacognitive activities in order to improve their learning (Pintrich, 1999).

Furthermore, science learning theorists (e.g., Tobin, 1993; Mintzes, Wandersee, & Novak, 1998) suggest that students who actively construct science knowledge and who engage in monitoring, evaluation and planning may be more successful science learners and therefore have higher levels of science learning self-efficacy, and vice versa. Prompts did encourage strategic behavior in this study. Strategic behavior is tied to success, which in turn is tied to self-efficacy. This may be the link between strategic behavior and motivation that Keller (1999) refers to. The author posits that cognitive and metacognitive prompts may serve a motivational scaffolding role in online learning environments. They may serve to increase self-efficacy and encourage metacognition. The findings of the present study are consistent with the notions from other researchers who claim that metacognitive prompting increases problem solving performance and efficiency through activation of reflection and strategy knowledge (King, 1992; Davis et al,

2000). Also students' reflection in response to these prompts plays a crucial role in their progress (Chen et al., 2009; Hatton and Smith 1995) as they become more strategic, autonomous and productive. It therefore appears in this study that prompts and self-efficacy bolstered success; however, a longitudinal study investigating this possibility is needed to ascertain this possibility.

## **EDUCATIONAL IMPLICATIONS**

The results of this study have at least two educational implications: the influence of self-efficacy and judicious use of reflective hints (metacognitive prompting) to facilitate problem-solving success. Given the typical constraints encountered in the classroom environment, such as lack of engaged time, educators should adapt methods to change both student self-perceptions and implement strategies to overcome problem-solving limitations. These findings inform self-efficacy literature as this study demonstrated the effect of self-efficacy and metacognitive prompting on problem-solving accuracy when controlling for background knowledge. The generalization of these results to other domains may not be warranted because self-efficacy is domain-specific.

## **CONCLUSIONS**

The significant metacognitive prompting and self-efficacy effects in the present study suggest the importance of both strategy and beliefs in genetics problem solving ability presumably by motivating the problem solver in positive ways. The finding that for students with high self-efficacy, increased metacognitive monitoring enhanced genetics problem solving ability means that high efficacious students, who believe that their work is interesting, important and useful, are more likely to engage in various cognitive and metacognitive activities in order to improve their learning.

The predictive model is stable as supported by the results of the cross-validation whereby the adjusted  $R^2$  shrinkage between the cross-validated sample and the training set was 0.035. Furthermore, regression analysis on CV sample showed consistency in the pattern of regression coefficients. The beta weights maintained their positive direction, with slight, negligible differences. The order of predictor importance remained unchanged with MP remaining the most important predictor. There was negligible difference in standard error of estimate for both samples. Therefore, the predictive model can accurately perform in practice by applying to other samples.

## **FUTURE RESEARCH**

The utilization of a similar methodology for more complex problem-solving tasks is encouraged. Future researchers may replicate this study with other data sources or a different population. Furthermore, a longitudinal study may provide more evidence of the influence of MP on GPSA.

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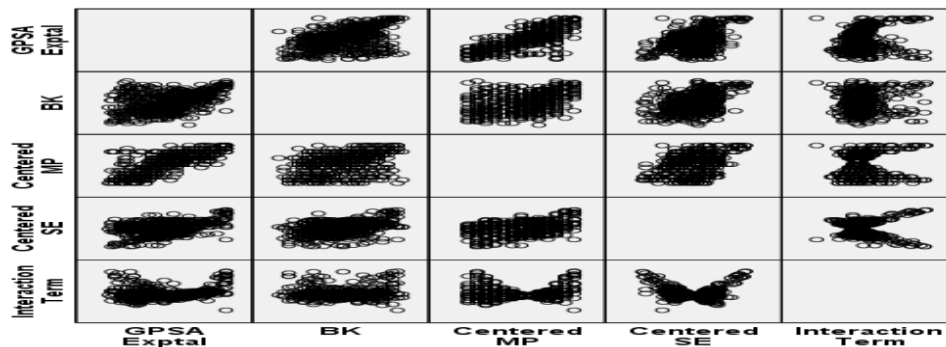
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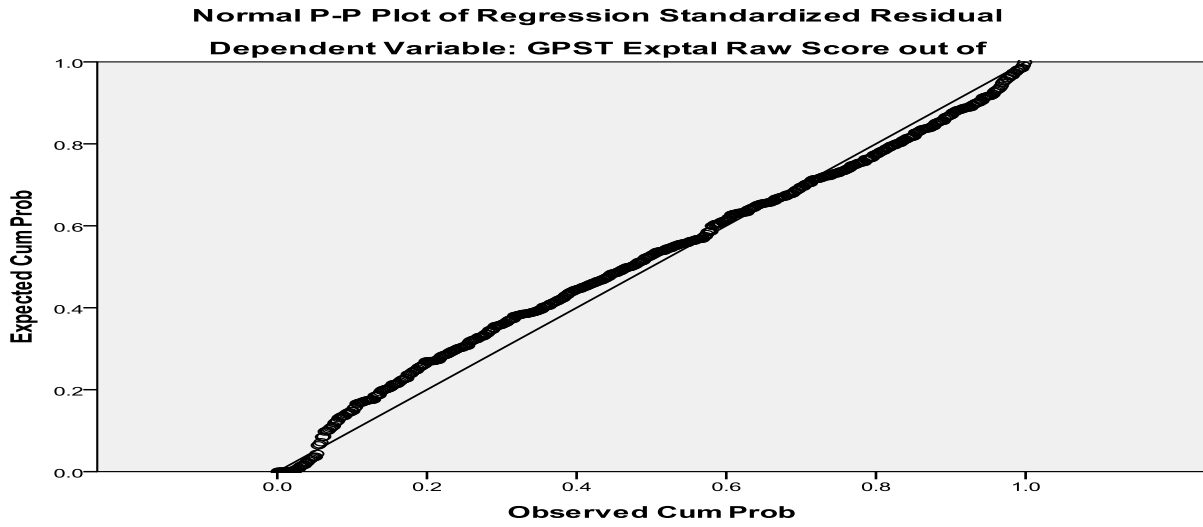
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## Appendice

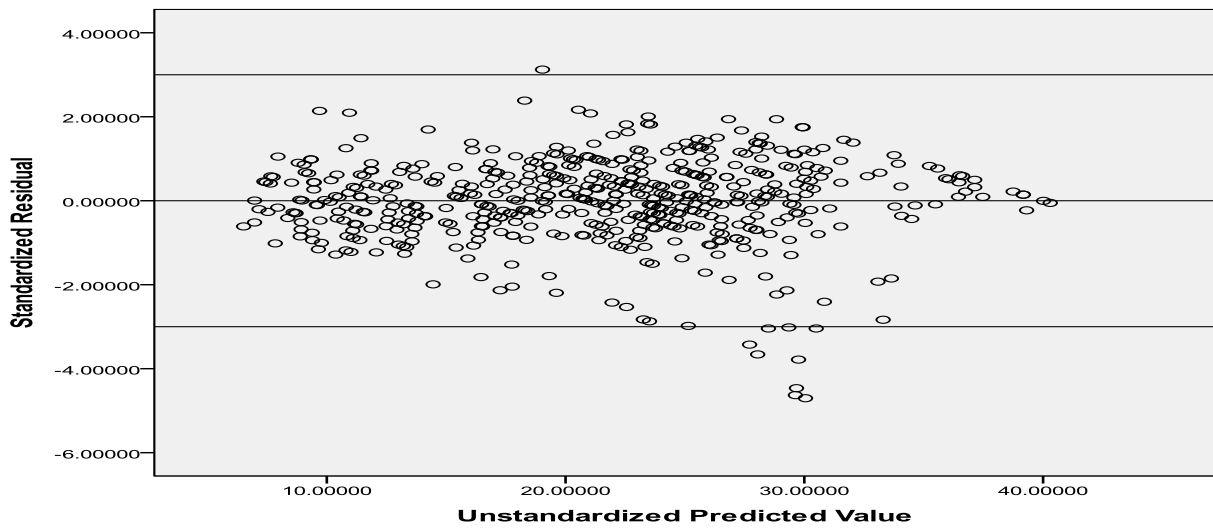
### Appendix A. Matrix Scatter Plot



### Appendix B. Normal Probability Plot



**Appendix C. Residual Plot**



**Appendix F. Summary of Collinearity Statistics for Training Sample**

Model		Collinearity Statistics	
		Tolerance	VIF
1	(Constant)		
	Score out of 30	1.000	1.000
2	(Constant)		
	Score out of 30	.755	1.325
	Centered MP	.761	1.315
3	Centered SE	.758	1.319
	(Constant)		
	Score out of 30	.750	1.333
	Centered MP	.757	1.322
	Centered SE	.756	1.324
	Interaction Term	.985	1.015