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**SOCIETY OF
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Effect of Teaching through Problem - Solving on Students' Performance in Mathematics in Secondary School in Murang'a County, Kenya

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Abstract

Students' are weak in curriculum outcomes in Mathematics at National examinations of secondary school education have been of concern to primary and secondary stakeholders. The concern was that result determines student's participation in science oriented programmes at tertiary level. Many interventions have been put in place to avoid but performance persisted. Science programmes support Kenya development agenda as described in the current vision 2030 including social, economic, political technological and industrial development. The pedagogical interventions had been done in various Counties. The study examined effect of teaching through problem – solving on students' achievements in Mathematics in secondary schools in Murang'a County, Kenya. This County was among 47 counties, but it was favoured because of climatic condition and assessable roads to schools. The study investigated students' performance in Mathematics for those taught using problem - solving strategies with those taught using conventional strategies. The study employed quasi – experimental design using Solomon Four Group model. The target population was 28485 students in 340 secondary schools in Murang'a County. These schools were purposely stratified into four categories according to their performance in national examination past four years. Four schools from each stratum were randomly distributed into four groups. Two groups E1 and E2 were assigned as experimental groups whereas other two C1 and C2 as control groups. A total of 16 schools: 8 schools experimental and 8 schools, control. Sample size of 544 students and 16 teachers were involved in the study. Pretest and posttest Students' Mathematics Achievement Questionnaire were constructed by national examiners and moderated by senior examiners not in sampled schools. Eight schools participated in pre-test in E1 and C1 and all 16 schools received post- test Mathematics achievements tests after intervention. In order to establish significance means difference between students taught through problem – solving and those taught through conventional strategies paired t –tests and Cohen's d effect measure were used. Problem – solving method improved students' performance and teachers should embrace facilitating Mathematics in an environment contributing to better achievement.

Keywords: *Mathematics achievement; Problem Solving; performance; Attitudes.*

1. Introduction

The foundation of all sciences and technology is Mathematics whose functional role affects the society in sciences, technology and business enterprises. The teaching of Mathematics in classroom is a contributing factor to good performance of students in Mathematics. Therefore, teaching Mathematics remained significant challenge which could be addressed by learning through problem – solving to improve students' achievement in Mathematics. Secondary schools Mathematics instruction and learning involves the learner, teacher and society. In order to achieve the intended aims and goals, the three must be involved. This study involved learners and teachers through problem – solving to obtain meaningful solutions to mathematical problems. The learner was involved directly in solving real life problems. This was done using problem - solving strategies in specified learning conditions in



secondary schools. These conditions provided different learning situations under controlled classrooms. Therefore, in this study, researcher focused on effect of teaching through problem - solving strategy on students Mathematics achievement in secondary schools of Murang'a County, Kenya. This study weighed importance on teaching Mathematics in context of problem - solving and enquiry - oriented environments characterized by teacher helping students to construct mathematical ideas while given profound opportunity in learning process.

The core target of high-quality Mathematics education is development of problem - solving abilities (Hull, Balka & Miles, 2011). Mathematics skills could be effectively passed through concentrated Mathematics instructional teaching strategies promoting learners' retention and understanding. Students' performances at secondary school level Mathematics continued to decrease every year. The poor Mathematics performance of the students becomes major concern among Murang'a County educational stakeholders. The students could not join medicine, engineering, business courses and even science teachers without a grade C+ (credit) in Mathematics. These prompt need for County stakeholders to look at the policy for teaching Mathematics. Skills to solve real life problems and everyday people are required to solve common problems in order to satisfy their various needs. Problem - solving is a long – life process which is practised in and out of school.

Students in Kenya were engaged in activities of demonstrated algorithm by their teachers in a procedural level which does not assist students' development of conceptual understanding. Study involved learners in organized groups to face the challenges of learning Mathematics in secondary schools. The study was carried out in order to determine whether using problem – solving approach to learning and teaching Mathematics in secondary schools of Murang'a County has any effect on students' achievement. These provided learners with an opportunity to generate investigative and explored solutions to unfamiliar problems. The learners worked in collaboration in small groups learning through plenty of discussion, solving problems in untried situations which were encouraged through problem - solving instructional strategy. The study enabled students to become resourceful aligned with the Country's National Goals of Education that learners solve problems competently. The intention was to make Kenya middle earning economy with technological innovations (Kenya Vision 2030, 2010). However, despite this, there was concern to those in Kenya that secondary school students Mathematics achievements have been on plummeting. The study was guided by the following objective to investigated students' performance in Mathematics for those taught using problem - solving strategies with those taught using conventional strategies.

This study focused on providing background that engaged student in an important recreation role to effect on teaching Mathematics through problem – solving approach to improve achievement in Mathematics in secondary schools in Murang'a County. The idea of improving students' Mathematics achievement became driving force for this study was undertaken to fill this gap. This research has shown that learners enhanced their content transfer and improved their achievement through learning mathematical problem – solving.

Problem – solving strategy as goal of learning Mathematics had been justified by number of educational theories of learning. These contributed to improving students' achievement in Mathematics. This study used three main theoretical literature review social constructivism, problem – solving and production theory. Constructivism was carefully planned philosophical viewpoint about the nature of facts which were an epistemological bearing as advocated by Piaget, Bruner and Vygotsky (McLeod, 2015). Problem – solving is measured to be higher order cognitive process and intellectual function. These theories were improved by Polya model in problem - solving. The production theory relates social constructivism and problem – solving to make the required achievement on students. There are three most important schools of thought advocated by constructivist theorist in education. These are constructivist learning theory, constructivist teaching theory and social constructivist theory. This study adapted social constructivism new approach in education that claims humans were better enabled to learn and understand information as they participate in its construction. Underlying principle behind social constructivism was that knowledge is constructed through social interaction of learners gaining possession of the results in the social processes. Social constructivism model is formulated from social realistic consensus and based on social communication of students. Students individually construct mathematical patterns according to their reasoning and experiences. This demonstrates way of action taken personally and in social setting in the class environment. Therefore, problem – solving as social constructivism in Mathematics learning, relates learner's known patterns to new concepts through interface connections.



Historically problem – solving has been the heart of educational objectives in which parents and teachers expect to achieve from their students as they shape capability in problem – solving for future generation (Saeed, Shahvarani & Behzadi, 2012). In the contemporary educational systems, teachers are expected to facilitate process of learning in which students are responsible and self-directed to solve Mathematics problems. Student have reproduced standard solutions or techniques provided by their textbooks. Minimum time is dedicated to teaching learners how to carry out investigative process.

According to Polya (2011), Mathematics is insightful, help understanding, reasoning and solving complex mathematical concepts through powerful problem - solving heuristics (Polya, 2011). Generally, experienced educationalists use analytical method as an instructional tool enhances learning when making Mathematics relevant and practical (Cox, 2011). While students are involved in problem - solving skills they promote their independent learning. Mathematics instructors believe that quintessence of learning Mathematics itself an implementation of skills in exploration, conjecture, examination and testing are all aspects of problem - solving. Learners were given opportunity to construct, build problems from assumed situations in order to create new problems through modifying conditions specified in the problem.

Problem – solving being critical component of comprehensive 21st Century Mathematics education since it invokes key skills in present day’s students as critical thinkers and problem solvers to achieve sustainable development goals (Lawson, 2016). Mathematics forms basis of decision making in many disciplines in our lives. Therefore, learning and facilitation in Mathematics should be heart of education. Learning Mathematics aims to link school to everyday life-giving skills required. Students acquired necessary techniques for workforce needed in fostering Mathematical thinking (Suurtamm, Quigley, & Lazarus, 2015). Mathematics involves learning how to solve problems. The mathematical investigation and presenting concepts in good communication of discovered concepts and ideas making connections to daily basis on contemporary life.

The constructivist classroom environment was place where both teachers and students contribute in knowledge development. Problem – solving in Mathematics causes dynamic of ever-changing real worldview to develop ability to solve problems successfully. These stretched inactive individual learners who waited drilling and committing to memory facts to active participants in learning. Executing mandate of problem – solving, it takes to consideration what student currently believes and experienced with correct or incorrect solutions. The special consideration for this question gives student an opportunity to make directly and decisively independent decisions on Mathematics learning which bears fruitful results on Mathematics achievement. A conceptual framework interconnected set of theories about how particular phenomenon was related to its parts. The study tried serve Mathematics understanding patterns through correlational on interconnection across concepts, facts and information. There were other learning experiences components accommodated in the classroom.

The independent variable of this study was problem - solving approach while dependent variables was learners’ Mathematics achievement score. The intervening variables included students’ attitude change through involvement of teacher’s competence. The constructivism theory recommends that knowledge is individually acquired and constructed socially as learners interpret present problem according to experiences. This study adapted investigation of teaching Mathematics through Problem - solving on foundation of Polya’s four stages, namely understanding the problem, devising plan, carrying out plan and looking back. Therefore, according to Polya problem - solving apply heuristic approach in which learners develop, explore, select and apply mathematical concept. Student’s understanding of the problem is guided from beginning to end process of mathematical inquiry. The conceptual framework was associated with social constructivism theoretical framework that views learning and teaching as active meaningful inquiry which built of knowledge by the learner initiative in Mathematics classroom interaction and culture. The variables are conceptually tied together as shown in Figure 1.



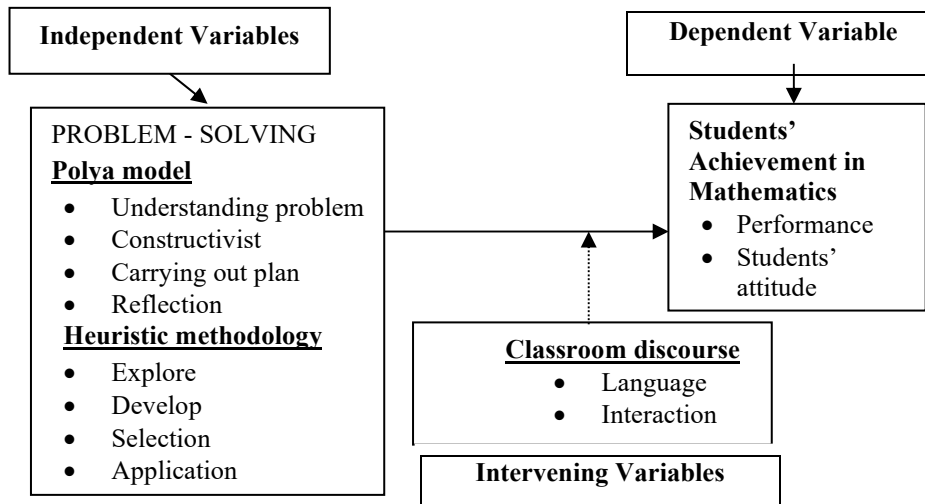


Figure 1: Researcher Adopted from Polya Conceptual Framework

2. Research Methodology

The researcher preferred quasi – experimental using Solomon Four Group design because it dealt with students in school setup. Solomon Four Group design was preferred since it overcomes problem of pretest sensitization while maintaining the benefits associated with conducting pretest. It avoids other difficulties connected with posttest. The design achieves this objective by random assigning participants’ groups to either receive or not receive pretest. Then randomly allocating these two factors of treatment and pretest where four conditions were created. Therefore, two control and two experimental groups were created to reduce influence of confounding variables. The category of schools was stratified depending on their four previous years Kenya Certificate of Secondary Education performances. The stratification was necessary since schools differed on performance although it was consistent in four years considered.

Form three class was used in this study where two groups of schools were experimental and two groups of schools were control. The reason for using form three class had learned basic concepts used and familiar in all schools subsequently in syllabus. The students had been together for two years and free to interact with each other. They were able to form opinions on attitude towards Mathematics. Four schools in each stratum were randomly distributed into four groups. Two groups E1 and E2 were assigned as experimental whereas other two C1 and C2 as control groups. Pretest and posttest Students’ Mathematics Achievement Questionnaires were constructed by national examiners and moderated by senior examiners not in sampled schools. Eight schools participated in pre-test in E1 and C1 and all 16 schools received post- test Mathematics achievements tests after intervention.

The design allows the researcher establish that whether pretest itself had effect on participants before treatment commenced. The study checks whether there was significant effect on student achievement scores when problem – solving used comparing scores of control groups and experimental groups after treatment. One of the treatment groups and one of the controls received pretest. The influence of the pretest by contrasting differences in posttest scores between both groups that received the educational treatment.

Study involved the independent variable which was problem - solving strategy through classroom activities and peer interaction. The independent variable through the treatment significantly affects outcome variable of students’ Mathematics achievement. These dependent variables included students’ conceptual growth and attitude towards Mathematics. The teachers preferred strategies were also considered in the manipulation of the experimental and control groups. Applications of education instructional strategies were classified into conventional methods. The experimental groups’ treatment was exposition of problem – solving approach.



The data analysis addressed hypothesis using statistical data collected was presented in tables and analysed using descriptive and inferential statistics. The analysis used to test hypotheses on performance in pretest and post - test achievement test used paired t –test and Cohen’s d. The analysed students’ responses for both descriptive and inferential data at significance level set at $\alpha < 0.05$. The effect sizes value was interpreted using Cohen’s (1988) categorization of effect sizes.

3. Research Results and Discussion

The objective compared students’ performance on Mathematics those taught using problem - solving strategies with those taught using conventional methods in secondary schools in Murang’a County.

This examined hypothesis that there was no statistically significant difference between means of students’ scores in control group who were taught using conventional methods and those taught through problem – solving strategy in experimental group in pre – test and post – test achievements scores.

The conceptual and cognitive growths in Mathematics are determined by achievement test complying with pre-test and post-test questionnaires. Students’ were expected to learn Mathematics through problem - solving strategy while others through conventional strategies. This study suggested that students’ conceptual understanding was developed better using problem – solving rather than procedural knowledge using conventional methods in secondary schools in Murang’a County.

Solomon four group designs reveals that various combinations of tested and untested groups with treatment and control groups’ results were weighed against each other. These allowed researcher deal with extraneous factors that may have or have not influenced results. E1, C1, E2, and C2 are exactly same in all four categories according to their previous national examination. They were drawn from four similar schools with same standards. The two groups participating during pre–test were Experimental group (E1) and Control group (C1). A pre-test was conducted before commencement of the treatment therefore; it was administered in schools involved groups in E1 and C1 prior to the experiment. The pre-test involved experimental, E1 and control, C1 groups. The results of pre – test performance per group was shown in table 1. The mean scores and standard deviation of the two groups E1 and C1 were computed.

Table 1: Students Pre – test Performance per Group

Combined group	NUMBER	MEAN	VAR	STDEV	Standard error	95% Confidence	T–value
E1	128	39.36	268.66	16.39	1.454	36.52 - 42.20	0.174
C1	147	36.57	249.22	15.79	1.307	43.02 - 39.12	
Combined	275	37.87	259.26	16.01	0.969	35.97 - 39.77	
Difference		2.79					

VAR: Variance ; STDEV: Standard Deviation

Table1, revealed that using independent statistical t-test there was insignificant difference in the mean scores of pre-test for the experimental (E1) and control groups (C1) at $t(274) = 0.174$, $p = 0.1528$ at $\alpha = 0.05$ where $p < 0.05$. This clearly indicated that students’ performance in the pre - test was similar and their level of understanding in problem - solving was identical. Table1, further illustrated that there was no significant means difference between control and experimental groups. The effect size of $d_s = 0.17$ from Cohen’s power test interpretation was noted as near zero (small effect). This had proved that groups were of equal strength in terms of performance in Mathematics achievement test before intervention was initiated.

Study commenced treatment on experimental groups E1 and E2, where students were taught using problem - solving whereas control groups C1 and C2 taught using conventional methods. Solomon Four Group designs employed in this study experimental group’s experiences intervention prior to post - test measure was affected on students’ Mathematics performance. The questionnaire of post - test was administered to similar participants in their respective schools in all categories of students. The post-test was containing composed twenty items which were based on similar topics as in the pre –test. The topics were also discussed during intervention applying problem - solving.



Table 2: Mathematics Achievement Post–Test for Combined Experimental and Control Groups

Variables	No of respondents	Mean score	Standard deviation	Standard error	95% confidence interval	
					Lower	Upper
Post – test E1	128	48.91	15.42	1.368	46.24	51.58
Post – test E2	126	45.80	14.24	1.274	43.31	48.29
Combined	254	47.37	14.90	0.937	45.54	49.20
Difference		3.11			-2.46	2.70
Post –test C1	147	38.15	16.26	1.346	35.52	40.78
Post – test C2	143	34.92	14.53	1.219	32.54	37.30
Combined	290	36.56	15.49	0.911	34.48	38.04
Difference		3.23			-2.42	2.59

Table 2 shows achievement of combined experimental groups post - test and combined control groups post - test. The given ideas about that were no significant means difference between both experimental groups E1 and E2 and both control groups C1 and C2. Table 2 presented combined data experimental and control groups. Results demonstrated control groups C1 and C2 have t - value 1.775 which is less than critical 1.96 at 95% confidence interval. As t – score is within this value, there was nothing to suggest any difference between the two means and the hypothesis was accepted. Table2 indicates difference between mean scores of the experimental groups E1 and E2 and control groups C1 and C2 with intention of showing post – test was found to be significant at 0.05 levels. When the two experimental E1 and E2 combined and two control C1 and C2 combined yielded Cohen’s d 0.71 which had moderate positive effect. Hence,

Null hypothesis there was no significant difference means scores of experimental group and control group on post –test was rejected.

Table2 had shown that effect students’ Mathematics performance after treatment of experimental, E1 group and control C1. These two groups received pre - test before intervention was commenced on E1. The two groups received post - test immediately after intervention to experimental groups. The result recorded There was significant difference between experimental and control group, since $5.63 > 1.967$ (p-value is small 0.0003), with positive moderate Cohen’s d effect 0.68 which was reasonable improvement. The results of Experimental group E1 which experienced pre – test and control group C2 which did not experience pre – test before intervention. Table 2, give an idea on post - test with the aim to show experimental group E1 and control C2 differ significantly in their mean scores. This predicted that intervention had effect during post – test. The two groups E1 and C2 $\alpha > 0.05$ and $t = 7.66$. This was evidence that problem – solving improved students’ performance $7.66 > 1.96$, the null hypothesis rejected. The Cohen’s d of 0.94 implies that there was large positive effect size of the means difference and p-value is too small.

The results of Experimental group E2 and Control group C2 which both did not experience pre – test before intervention. Table 2, provided post - test effect showing experimental group E2 and control C2 differ significantly in mean scores. This envisaged that intervention had moderate positive effect during post – test withCohen’s d of 0.76. The two groups E2 and C2 $\alpha > 0.05$ and $t = 8.67$. This was evidence that problem – solving improved students’ performance $8.67 > 1.96$, the null hypothesis rejected. The Cohen’s d of 0.50 implies that there was moderate positive effect size of the means difference and p-value is too small between E2 and C1.

This study took ten weeks to avoid historical and maturation. This was reasonable period to observe that problem – solving validly affects students Mathematics learning outcomes. The study investigated difference between students taught through problem – solving and those taught using conventional approach. Problem – solving approach used in this study applying constructivism where students construct knowledge through their experiences. Students are actively involved increasing enjoyment and social skills in communication. Problem – solving provided an opportunity for young mathematician to explore ideas to improve their achievement.

Table 2 demonstrated that there were significant mean differences in the student performance in the post - test between four groups. The second null hypothesis is then concluded.



The test null hypothesis (H_0) states that, there was no statistically significant differences between means on students' achievement in Mathematics in secondary schools of Murang'a County to those taught through problem - solving approach and those taught using conventional strategies in post -test.

4. Conclusion

The study concluded problem – solving employed in learning Mathematics increases students' achievement (performance) rather than instructing making use of conventional approach. Therefore, hypothesis (H_0) which was stated students' performance in Mathematics when taught using problem - solving approach is better than those taught using conventional strategies during post - test in secondary schools in Murang'a County. The hypothesis was rejected since this result was statistically significant. There was enough evidence to reject claim that groups which received pre – test and those given post – test only shows that intervention had been effective. The acceptance that teaching through problem – solving improves student Mathematics achievement. The opinion that teaching through problem - solving trigger critical thinking in class discussion reacted against criticism conventional methods are better. The cognitive skills and holistic learning environment for students through problem – solving should be encouraged in secondary schools Mathematics teaching in Murang'a County.

Study supported knowledge of social constructivism theory where students constructed knowledge in their classroom experiences rather than absorbing what they were told. The constructivist views the student as active learner who in process of struggling with a problem obtains solution. The learner gets deep understanding of Mathematics concepts since problem – solving provides students an opportunity to explore ideas and given chance to extend their creativity. This study completes gap that using problem – solving strategies improves students' achievement in Mathematics rather than integrated conventional strategies in view of fact that it becomes learner – centred rather than teacher – centred.

The mathematical modeling approach as effective problem – solving strategy as appropriate to educating and learning Mathematics. This study used a language to enable student interpret Mathematics problem and make meaningful way to device plan for solving problem. The teacher's role changes from designing and selecting problems to a guider and participant in classroom environment. This is new pedagogical trends in 21st century Mathematics teaching involving integration of problem - solving to competency in classroom discourse. Beyond promoting Mathematics problem – solving, it fosters development valued life skills and disposition goals important for students' as long-life learners. This means that students do not only use Mathematics for academic purposes, but as future adults who solve problems in challenging ventures. The teachers who participated in intervention noted that engaging students in problem - solving activities improves student perseverance, independence, critical thinking skills and general communication.

5. Recommendations

The study used problem – solving approach as an effective instructional strategy to improve student Mathematics achievement. This was done by providing students appropriate opportunities engaging freely in problem – solving activities. The study has shown that general problem - solving strategy has been successful in secondary schools practice even in all categories. The students develop habit of mint support ones' idea or request opinion of another. This implies that they develop logical thinking, not restricted to Mathematics, but have willingness to have dialogue. Teachers noted that problem solving has influence in social relations. The classroom was Mathematics community whose impact of social dynamics trusted figurative things themselves or use their peers as human resource.

The study adds literature of learning Mathematics through problem - solving activities. These activities were done in an environment encouraging students to interact freely and discover concepts themselves. Classroom environment providing students with variety of learning material and culture through social context experiences was one of limitation of this study. These classrooms learning materials including human resources, improvisation of materials within environment and relation of content to real world creates enjoyable classrooms. This improved conceptual growth, attitude change, build confidence and create a community of young Mathematicians who care for each other. The current study did detest that problem - solving is desired teaching approach preferred rather conventional strategies. This study differs from other researches by encouraging teacher to apply constant interventions to direct students to the critical thinking. This was aligned to 21st century pedagogical trends in teaching Mathematics through integrating problem –solving for competency in the classroom.



Mathematics teachers in secondary schools should embrace using problem – solving approach to improve students Mathematics achievement. Emphasized use of problem - solving to change pedagogical skills employed in learning Mathematics must focus more on understanding rather than current mastery of algorithms. Students need more time to understand mathematical concepts. This study was competently corrected answer to question what should be done in secondary schools in Murang'a County to improve students Mathematics achievement. The development of required deeper of understanding of Mathematics concept produces results.

This study focused on improving student achievement in Mathematics through teaching Mathematics using problem-solving strategy. The teachers' using conventional methods that emphasize on self-discovery of knowledge and interactions of students were used. Students who received instruction through problem - solving had acquired more self – driven information better than their peers without much instruction raising their achievement scores higher. Therefore, the study recommends that students in secondary schools in Murang'a should be taught Mathematics through problem - solving. The students cognitive learning domains and improve their achievement in Mathematics.

Study recommends that teachers provide students with opportunities to interact in favourable rich environment to solve problems. Students actively participate to finding individualized solutions applying problem – solving strategies. This happens when teachers encourage and give opportunities students to share and compare their answers. Students further contrast their methods is general idea of this research where problem – solving involves individual solution with activities in small groups and whole class. This enhanced through classroom interaction and creating class communication providing students with confidence in problem – solving. This increases student Mathematics achievement through problem – solving activities through problems and assignments.

The study concluded that well - developed, planned and executed problem - solving instruction can significantly improve students' achievement in Mathematics in secondary schools. Mathematics can effectively be instructed applying problem - solving strategies to promote Students' interest towards Mathematics. This could be done by fully prepared lesson using problem - solving strategy which more of student - centred rather than teacher - centred. The teacher through planned intervention that involve students in problem –solving student develop perseverance, independence, thinking skills, general communication and support others ideas helping them in social activities. These skills are life skills through which assist them to take part in challenging ventures.

The Mathematics teachers training institution prepare student to using problem – solving learning approach. This would build the student teachers confidence in applying the problem - solving strategies in their classrooms. Government curriculums development centres orient curriculum to problem –solving to improve students' achievement in Mathematics in secondary schools. This might includeextensive training program, seminars and workshops organized for Mathematics teachers in secondary schools to enable employ problem - solving method in the classrooms. Government must provide incentive that attract and retain competent, fully prepared qualified teachers. The schools should assure Mathematics teachers good classroom environmental conditions to teach effectively in a reasonable class size. The teacher – educators should put emphasis on teacher preparation using problem – solving so that processes and essential content of Mathematics is fully integrated. The learning activities involving teachers' trainee allow them opportunities to form connections between procedures and outcomes of problem – solving.

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