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Effects of Gowin's Vee Heuristic Strategy on Secondary School Students' Conceptual Understanding and Metacognition in the Topic of Moments in Physics, in Uasin Gishu County, Kenya

Daniel K. Mutai[1*] Johnson M. Changeiywo[2] Mark I.O.Okere[3]
1. Faculty of Education Egerton University P.O Box 536-20115 Egerton,Kenya
2. College of Open and Distant Learning ,Egerton University P.O Box 536-20115 Egerton,Kenya
3. Faculty of Education Egerton University P.O Box 536-20115 Egerton,Kenya
* Dankamutai@yahoo.com

Abstract

Physics is a science subject that has contributed immensely to the technological advancement of the world. In the Kenyan 8-4-4 curriculum, it is optional at form three and four. However, physics in Kenya has been faced with poor performance. Consequently, many students drop out of the subject on moving to form three. The cause of this trend has not been fully concluded. On the contrary, many have attributed it to poor instructional methods. This study, therefore, attempts to change this trend. It collected data on the effects of Gowin's Vee heuristic strategy on students' conceptual understanding and metacognition in physics among secondary schools in Uasin Gishu County. It was carried out in physics classroom setting. Solomon four quasi-experimental design was used. Two experimental groups were taught using Gowin's Vee as treatment and two control groups were taught using conventional methods. The target population was 3735 form two students in 83 mixed secondary schools in Uasin Gishu County. Purposive sampling was used to select 134 students to the control and experimental groups. The instruments used were Physics Metacognitive Activity Inventory Questionnaire (PMCAIQ) to test their metacognition and Physics Conceptual Understanding Achievement Test (PCUAT) to test conceptual understanding. The validity of the instruments was determined by supervisors and examination experts from the department of Curriculum, Instruction and Educational Management as well as physics teachers. Reliability of instruments was done using the coefficient of alpha for both instruments. The study found Coefficient of alpha 0.75 and 0.78 for PCUAT and PMCAIQ respectively, hence they were reliable. The data was subjected to descriptive statistics such as mean and standard deviation. Also inferential statistics was done using t-test and one way ANOVA at 0.05 significance level. These were followed by post hoc analysis. The analysis was done by Statistical Packages for Social Sciences (SPSS). This study is important in enhancing performance and quality of teaching in the topic of moments in physics and sciences in general.

Keywords: Gowin's Vee, Heuristic, Strategy, metacognition, Conceptual understanding, Physics

1.0 Background Information

The learning requirement in the twenty first century is to develop life-long skills for learners to cope with the various emerging challenges being encountered. Physics knowledge and skills are among the most required for one to face these challenges especially in high technological advancements being witnessed today (Musasia, Abacha & Biyoyo, 2012). Physics is made up of experiments, calculations, graphs, symbols, equations as well as conceptual explanations and applications experienced in its topics (Angell, et al., 2004). Each topic presents its own level of learning challenges (Waititu, 2004). This has made many students to perceive the subject as difficult leading to low enrolment and poor performance (Menjo, 2013). Consequently most students see physics as made up of memorization of information and problem solving procedures that apply to specified situations and not their life experience (Ornek, Robinson & Haugan, 2008).

Research in teaching methods has proved that these challenges can be addressed by applying the relevant teaching methodology. Effective physics instruction should be able to change students' way of thinking about physics. In an attempt to achieve these, various contemporary researches in education and psychology have come out with epistemologies, theories and pedagogy like constructivism and meaningful learning theories(Ausubel,1968), metacognition (Flavell, 1979), creativity and process skills (Okere, 1996), advanced organizers (Ausubel,1968), Gowin's Vee (Gowin, 1981) and concept maps (Novak & Gowin, 1984) among others. These have shifted physics education from building the knowledge capacity to improving thinking skills

and creativity through conceptual understanding. Thus the use of socio constructivist perspective and meaningful learning theory has offered a window of hope in the teaching and learning of various topics in physics and science in general. Students should be made to understand the physics world as made up of coherent structure of concepts which are interlinked together (Ausubel, 1968; Novak & Gowin1984).

The other two meaningful learning tools, concept maps and advanced organizers, were developed on conceptual and theoretical framework of the new knowledge that the student must learn. However, they do not address relationships between activities and concepts required in order to acquire the knowledge being sought (Gowin 1981). Gowin's Vee offers a solution to this by combining both the theoretical knowledge to be learned with the activities to be performed in one unit of a Vee. Gowin's Vee is a very useful teaching and learning tool which has been extensively used in many other countries like USA (Novak & Gowin, 1984), Finland(Ahlberg,1993),Australia (Afamasaga,1998),Venezuela (Ramírez ,Aspéen, Sanabria & Tellez, 2008) and South Africa (Ramahlape, 2004) among others in bringing about meaningful learning.

The Gowin's Vee heuristic, apart from including the concepts in the left hand side, it includes activities in the right hand side of its V-structure. These enable the learner to understand the nature of scientific knowledge as being both theoretical and practical (Novak & Gowin, 1984).The theoretical side consists of world view, philosophy, theory, principles, constructs and concepts. The methodological side includes records, transformations, knowledge claims and value claims. At the tip of the Gown's Vee diagram are events or objects to be studied which interact with both sides in order to achieve the answer to the focus question (Novak &Gowin, 1984). Figure 1 shows Gowin's Vee heuristic with a description of all the twelve epistemological elements.

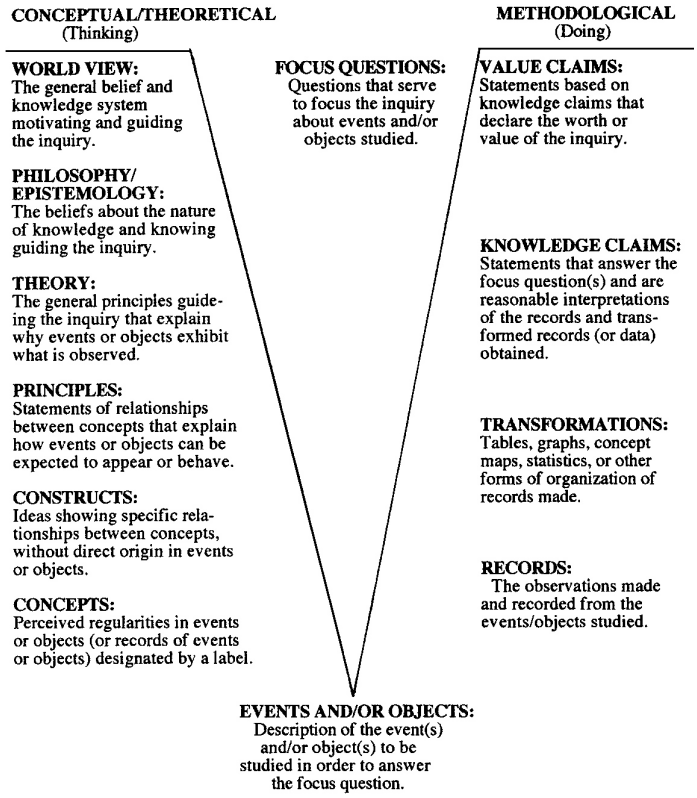

Figure 1: Gowin's Vee heuristic Twelve Epistemological Elements (Gowin & Alvarez 2005 p 36).

When using the Gowin's Vee in the teaching and learning process it is important that the learner starts by filling in the focus question under investigation at the centre of the Gowin's Vee. Then writes down any of the activities, procedures, descriptions, apparatus objects and events needed in order to answer the focus question. In the conceptual side the learner indicates the theories, principles, constructs (formulae) and concepts used in the study (Afamasaga, 1998).

Under records section, in the methodological side, the learner fills in data in tables or audio- visual form. In the transformation section the learner analyzes the data using graphs, calculations and charts. The answer to the focus question is written under the knowledge claims section. Finally, the relevance and importance of the knowledge attained is written under the value claims. After filling in all the sections of the Gowin's Vee, the

learner relates both sides which lead to conceptual understanding of the scientific knowledge sought. Therefore the learner retain the knowledge for a long time and reproduce it at any time using the basic structure of a Gowin's Vee heuristic. These make this learning process meaningful (Novak &Gowin, 1984)

It is of great importance for this teaching tool to be extensively used in teaching science in Kenya which may change the trend of rote learning in science (Namasaka, Mondoh & Keraro, 2013). In Kenya, Physics, Chemistry and Biology science subjects are offered in its 8-4-4 curriculum (KIE, 2002). A student is required to choose at least two sciences upon transition from form two to form three. However, during this transition many students drop out of Physics leading to low enrolment in the subject as shown in table 1.

Table 1: Candidates overall enrolment in KCSE examination 2008-2013

Year	Overall No of Candidates	Physics		Chemistry		Biology	
		No	(%)	No	(%)	No	(%)
2008	305015	93692	30.71	296937	97.35	274215	89.90
2009	337404	104883	31.09	329730	97.73	299302	88.71
2010	357488	109811	30.72	347364	97.17	317135	88.71
2011	411738	120074	29.16	403070	97.89	365458	88.76
2012	434121	118508	27.30	427303	98.43	386538	89.04
2013	445800	119862	26.89	439941	98.69	397314	89.12

Source: (KNEC, 2014)

From table 1 it can be observed that for the eight year period (2008-2013) even though there is increase of the overall number of candidates each year the enrolment in physics has remained at 31% and below. This is a very low number considering the other two sciences chemistry and biology in the same group have at least 90% and 80% enrolment respectively.

The low enrolment in physics has been attributed to poor performance partly blamed on teaching methods among other factors (Uside, Barchok & Abura, 2013).Many students perceive the subject as difficult as established by Musasia et al. (2012). Consequently, many opt out of the subject despite its importance (Nyakan, 2008). It is against this background that this study joined other studies in Kenya in exploring for the appropriate teaching approaches. It undertook the use of the Gowin's Vee heuristic strategy in the topic of moments in form two. The topic of moments in physics is among those perceived to be difficult by 40% of teachers (CEMASTEA, 2011). The Gowin's Vee heuristic has both conceptual and methodological parts and by going through the twelve stages the learner combine the concepts and activities being sought in the problem they are investigating. During the process they create conceptual understanding and metacognitive awareness. Metacognition is the process by which the learner is able to plan, monitor and evaluate their own learning process (Gowin &Alvarez, 2005).

Many teachers in Kenya use expository method which is teacher dominated learning process (Changeiywo, 2000; Kiboss, 2002). Few attempts are made to develop students' conceptual understanding and metacognition. There is no relating of new content to the learners environment so as to create meaning to the learner. These reduce learning into rote memorization of facts (Alvarez & Risco, 2007). As Driver (1987) reaffirms, in the expository method, there is a lot of emphasis on absoluteness of the content where students are supposed to just accept the content given to them. Ausubel (1963, 1968), Alvarez and Risco (2007) and Gowin and Novak (1984) have stressed the need to use meaningful learning strategies so that the already existing knowledge of the learner is related to the new knowledge and wrong conception of the learner is clarified.

The poor performance in sciences and mathematics in Kenya has led the Ministry of Education Science and Technology (MOEST) to introduce an annual teacher in-service training called Strengthening of Mathematics and Science in Secondary School Education (SMASSE) in 1998 in collaboration with Japan (JICA, 2007). In March 1999, SMASSE project Cycle one carried out a baseline study involving nine districts. In the study, at least 40% of teachers rated the topics of moments, magnetic effect of electric current and waves as difficult (CEMASTEA, 2011). According Menjo (2013) secondary school students found the topic of moments to be difficult. Also KNEC (2005, 2011) observed that in questions concerning moment of a force the students were

able to state the principle of moments but failed to translate the law in relation to the activities they were doing in the KCSE practical exam. This made them perform poorly in those questions.

The SMASSE project emphasized the use of experimental method and improvisation to deal with the problems facing the topics leaving out other strategies of learning like the Gowin's Vee heuristic. Furthermore, the topic of moment of forces in Form two is very applicable in the learners' day to day lives. It contains many activities that are used to verify its principles. The topic plays a pivotal role in topics like equilibrium and centre of gravity, states of equilibrium, work energy and machines and floating and sinking. These make it relevant for this study. This study emphasized on the need for the learning process in Kenya to be meaningful through Gowin's Vee conceptual and methodological approach of the physics knowledge.

The many strategies of learning science influence understanding and performance only to a certain limit (Mintrez, Wandersee & Novak, 2005). Therefore, there should be focus on combining them with other important aspects affecting learning like metacognition, attitude, motivation, and self-efficacy. Metacognition is the ability of the learner to plan, monitor and evaluate their own learning process. It has become such an important aspect in education. Furthermore, metacognition has attracted many educators because it has potential for teaching thinking skills and to enhance transfer of knowledge across various subjects, topics, school situation and everyday problems at home and workplace (Wittrock and Baker, 1991).

Learners who have good metacognitive skills learn better by identifying the objective in a problem, choosing the strategies used to achieve the objective, being observant of their own process of knowledge processing and carrying out a quick evaluation to verify whether the objective has been achieved or not. On the other hand learners, who have poor metacognitive skills have impulsive attention, make premature conclusions, lack reflective thinking and get stuck on one point without progression which lead to poor learning (Brown 1987).

Consequently, the future characteristic of successful science is attributed to metacognition and conceptual understanding. The methods used by the teachers either improve or reduce the metacognitive tendencies of the students. This called for the use of metacognitive tools like the Gowin's Vee. Using these teaching and learning tools develop creative and reflective persons, with ability to change society (Mintrez, Wandersee & Novak, 2005). When using the Gowin's Vee heuristic the learner goes through the process of metacognition which includes planning, evaluating and monitoring the learning process. Therefore, the Gowin's Vee heuristic goes further to facilitate the development of students' metacognitive skills (Tobias & Everson, 2002).

The elements in the Gowin's Vee diagram can be interpreted to suit any educational level and curriculum content as long as the basic structure remains. Therefore, during this study the Gowin's Vee heuristic was made to suit the level of the learner and Kenyan secondary school curriculum. For instance, in secondary school level the world view and philosophy elements of the Gowin's Vee heuristic can be left out (Afamasaga-Fuata'i, 1998). Novak (1998) prediction that it may take several decades before the Gowin's Vee heuristic is fully utilized in the teaching and learning process. However, many researchers have acknowledged the importance of the Gowin's Vee and emphasized that its use should not take too long before it is utilized. This is because of its power to capture and facilitate the thinking process of the learner (Piyush & Robert, 2006). The role of the Gowin's Vee has not been fully realized in Kenya. This is supported by Namasaka et al. (2013) that there is need to use Gowin's vee heuristic in Kenya since it has potential to improve students' motivation and does not depend on gender.

1.1 Purpose of the Study

The purpose of this study was to determine the effects of Gowin's Vee heuristic strategy on secondary school students' conceptual understanding and metacognition in the topic of moments in physics, in Uasin Gishu County.

1.2 Research Objective

i. To investigate the effects of using Gowin's Vee heuristic strategy on secondary school students' conceptual understanding in the topic of moments in physics.
ii. To investigate the effects of using Gowin's Vee heuristic strategy on secondary school students' metacognition in the topic of moments in physics.

1.3 Research Hypothesis

H_O1: There is no statistically significant difference in conceptual understanding between students taught using Gowin's Vee and those not exposed to it, in the topic of moments in physics.

H_O2: There is no statistically significant difference in the level of metacognition between students taught using Gowin's Vee and those not exposed to it, in the topic of moments in physics.

1.4 Research Design

In this study Solomon-four Quasi Experimental design was used as shown in figure 2. Solomon- Four, according to Frankel and Wallen (1990) is suitable in experimental and Quasi-experimental research because it can control all the threats to internal validity. Quasi-Experimental design is adopted because under school arrangement the students have already been assigned classes and cannot be randomly constituted during the study. This cannot be authorized in the schools since it will affect the laid down criteria for which they were initially constituted. Figure 2 shows structure of Solomon four quasi experimental design.

1st Experimental group (E_1)	O_1	X	O_2
1st Control group (C_1)	O_3		O_4
2nd Experimental group (E_2)		X	O_5
3rd Control group (C_2)			O_6

Key

------ = No randomization is done

X =treatment results

O_1 & O_3 =pretest results

O_2, O_4, O_5 &O_6=Post tests results

Figure 2: Solomon Four Quasi-Experimental Design (Cohen & Manion, 1990)

1.4.1 Sample Size and Sampling Procedure

In Uasin Gishu County there were 83 mixed district secondary schools. Out of these only four were selected purposively to ensure that there was equivalence in terms of resources, performance in national examination and boys and girls well represented. This was done by checking their background performance including KCPE entry marks. To get the sample size from the four mixed district schools one class was used. Each class has at most 45 students. However, in the study E_1 had 31 students, E_2=31, C_1=42, C_2=30, giving a total 134 students. There were 83 boys and 51 girls in the sample.

1.4.2 Instrumentation

A physics conceptual understanding achievement test (PCUAT) was used to measure students' conceptual understanding in the topic of moments. This is an achievement test constructed by the researcher under close monitoring by the supervisors. It consists of two structure questions with subsections. First question covers the principle of moments and the second question covers sum of upward and downward forces under equilibrium as well as moment of couple of forces. Therefore it covers the entire topic exhaustively. Each question was answered by filling in the twelve epistemological elements of the Gowin's Vee. The students incorporated the applications of the topic under value claims which is the last element of the Gowin's Vee. Gowin's Vee has twelve 12 epistemological elements each earning marks according to Gowin's Vee scoring criteria (Gowin &Novak 1984) the marks were converted into percentage.

Physics Metacognition Activity Inventory questionnaire (PMCAIQ), a 27 item 5-likert scale questionnaire adopted from Cooper and Sandi-Urena (2009) was slightly modified and administered to measure student's metacognition in physics. The instrument was originally tested using problem solving in chemistry. It was found to have Cronbach alpha of 0.70 and therefore it was reliable. This study used it in the topic of moments and obtained a Cronbach alpha of 0.78.

For instance one of the question is 'I use graphic organizers (diagrams, flow-charts, concept maps and Vee heuristics etc) to better understand physics problems'. The respondent was supposed to respond in five way by circling the following numbers :1 = Never or only Rarely ,2= Sometimes,3= Half of the time, 4 = Frequently and 5 = Always or Almost Always.The values indicated are commensurate with the marks given to the answer with positive connotation questions. However in questions with negative connotation the marks are reversed e.g. 'I do not check that the answer makes sense' 5 = Never or only Rarely 4= Sometimes, 3= Half of the time, 2 = frequently and 1 = Always or Almost Always. There are eight negative questions in the questionnaire. The questionnaire tested students on planning, monitoring and evaluation which are elements of metacognition. Evaluation has 12, monitoring 10, and evaluation 5 questions. The overall total score was 135. Thus the scores of each student were done out of 135 and made into percentage.

1.5 Results and Discussions

1.5.1 Effects of using Gowin's Vee Heuristic Strategy on Secondary School Students' Conceptual Understanding in the Topic of Moments in Physics.

The first objective of this study was to determine the effect of using Gowin's Vee heuristic strategy on students' conceptual understanding in the topic of moments in form two physics. In order to achieve these objectives, Solomon four quasi experimental design was used. Four schools were selected purposively. The first, second, third and fourth schools were grouped into first experimental group (E_1), second experimental (E_2), first control group (C_1) and second control group (C_2) respectively. E_1 and C_1 were pretested while C_2 and E_2 were not pretested. The teaching of the topic of moments using Gowin's Vee heuristic strategy was done in the experimental groups $E_1$and E_2.

Regular expository teaching method was used in control groups C_1 and C_2. Physics Conceptual Understanding Achievement Test (PCUAT) was administered at the end of the topic. The examinations were marked and analyzed against the hypothesis that there is no statistically significant difference in conceptual understanding between students taught using Gowin's Vee and those not exposed to it, in the topic of moments in physics. The pretest results are summarized in table 2.

Table 2: Comparison of Pretests and Posttests Mean Scores and Standard Deviation obtained by the Students in PCUAT Exam.

Exam	Overall N=207	E_1(N=31)	E_2(N=31)	C_1(N=42)	C_2(N=30)
Pretest means	-	38.39	-	39.05	-
SD	-	9.06	-	8.90	-
Posttest means	44.94	60.43	56.77	40.00	38.66
SD	12.88	9.26	9.40	9.31	9.96

From table 2, the pretest examination means scores for the control group (C_1) and experimental group (E_1) are 39.05 and 38.39 respectively. Their standard deviations (SD) are 8.90 and 9.06 respectively. These results show that the two groups are similar prior to the introduction of the PCUAT. It can also be observed that the posttest mean scores after introduction of Gowin's Vee heuristic strategy for the experimental groups E_1 and E_2 are 60.43 and 56.77 respectively. These scores are higher than those scored by the control groups $C_1$and C_2 which are 40.00 and 38.66 respectively. To test whether the means of the pretest of experimental group E_1 and control groups C_1 were statistically significant, t-test was done as shown in figure 3.

Table 3: Independent Samples t-test of Pretests E_1 and C_1 Mean Scores in PCUAT Exam

PCUAT	Levene's Test for Equality of Variances		t-test for Equality of Means		
	F	Sig.	T	Df	Sig. (2-tailed)
Equal variances assumed	0.517	-0.311	0.757	71	0.757
Equal variances not assumed			0.758	64.16	0.758

Critical $t_c(71)=1.667$ $p<0.05$ Calculated $(71)=0.757$ $p<0.05$

The independent t-test value $t(71)=0.757$ $p<0.05$ is less than the critical value which is 1.667.
This shows that the means of the two groups E_1 and C_1 are not statistically significant and were similar before treatment. As a result of these an ANOVA test was carried out to test whether the change in scores is significantly different at 0.05 α-level as shown in table 4.

Table 4: Summary of One Way ANOVA of Posttests Mean Scores obtained by the Students in PCUAT

SOURCE	*Sum of Squares*	*Df*	*Mean Square*	*F*	*Sig.*
Between Groups	12465.061	3	4155.020	46.314	.000
Within Groups	11662.746	130	89.713		
Total	61824.876	133			

Critical value F_c $(3,130=2.67, p<0.05)$ Calculated value F $(3,130=46.314, p<0.05)$

One Way ANOVA analysis of PCUAT in table 4 produce an F-ratio of $F(3,130=46.314, p<0.05)$ this value is greater than the critical values $F_c(3,130=2.67, p<0.05)$ showing that the results of students who used Gowin's Vee heuristic strategy were higher and statistically significant at 0.05 level. To confirm this further, Tukey's Honest Significant difference was carried out to determine the actual difference between each group as shown in table 5.

Table 5: Tukey's Honest Significant Difference Post Hoc Analysis for PCUAT Examination

COMPARED	RESULTS	MEAN DIFFERENCE	P-VALUE
Posttest E1	Posttest E2	3.66	0.429
	PosttestC1	20.43*	0.000
	Posttest C2	21.76*	0.000
Posttest E2	PosttestC1	16.77*	0.000
	Posttest C2	18.11*	0.000
PosttestC1	Posttest C2	1.33	0.935

*significant at $p< 0.05$

Tukey's honest significant difference post hoc analysis confirms that the mean difference between the experimental groups' posttests E_1 and E_2 is 3.66 hence they are not statistically significant at 0.05 α-level implying that they are similar. However, there is statistically significant difference between the experimental posttests' scores E_1 and E_2 compared to the control groups' posttest scores C_1 and C_2 :(E1 -C_1=20.43*, E_1-C_2=21.76*, E_2-C_1=16.77*, E_2-C_2=18.11*).

It is can be concluded at this point that the Gowin's Vee heuristic strategy was effective and students attained

higher results on using it. Owing to the above results and analyses, it is safe at this juncture to reject the null hypothesis and confirm that there is statistically significant difference in conceptual understanding between students taught using Gowin's Vee heuristic strategy and those not exposed to it, in the topic of moments in physics.

The finding is in agreement with Gowin (1981) who designed it to enable students relate the activities in the laboratory and the scientific concepts, principles, laws and theories and hence conceptual understanding. More so Novak and Gowin (1984) added that the interplay of the methodological and conceptual side promote conceptual understanding of knew content being learnt. It allows the learner to organize their cognitive structures into discernible, more powerful integrated patterns whereby learners examine the conceptual, rational and hierarchical nature of the knowledge.

Rote memorization which is a problem in expository method (Driver, 1987) can be avoided. when using the tool the learners construct knowledge on their own making the learning process meaningful. Owing to these the learners uncover the structure of a given scientific investigation by planning and analyzing experiments so that there is connection between unknown and the known knowledge(Novak &Gowin ,1984).These stimulate the mind to think critically (Gowin & Alvarez, 2005). In addition to these Alvarez and Risco (2007) found that the tool improves conceptual understanding. In their undertaking in biology studies the learners assimilate, predict, question, connect, and structure knowledge generating their own meaning.

The results also concur with Gowin and Alvarez (2005) that it is a tool to aid in understanding meaningful relationships, planning, analyzing in experiments, during learning. It unpacks information that stimulates the mind to think critically and examine the structure of a given scientific investigation so that there is connection between the known knowledge and the new knowledge to be learnt. The influence of the tool in conceptual understanding was also established by Åhlberg and Ahoranta (2002) whereby it promotes deep, meaningful and creative learning. Its success in creating high level of understanding according to Fox (2007) is due to its cohesive structure.

Afamasaga-Fuata'i (1998) and many of her very extensive research in mathematics produced similar results that Gowin's Vee heuristic mapped the students' understanding and they developed deep understanding of structure of mathematics. She emphasized that it is an effective tool in guiding the critical thinking and it is a systematic approach for the analysis of the structure of knowledge in a mathematical problem.

1.5.2 Effects of using Gowin's Vee Heuristic Strategy on Secondary School Students' Metacognition in the Topic of Moments in Physics.

The study investigated the students' level of metacognition after being exposed to the Gowin's Vee heuristic strategy measured by Physics Metacognitive Activity Inventory Questionnaire (PMCAIQ). Table 6 compares students' pretests and posttests mean scores and standard deviation in PMCAIQ.

Table 6: **Comparison of Pretests and Posttests Mean Scores and Standard Deviation obtained by the Students in PMCAIQ Exam.**

Exam	Overall n=207	E1(N=31)	E2(N=31)	C1(N=42)	C2(N=30
Pretests means	-	66.24	-	63.97	-
SD	-	5.43	-	8.53	-
Posttests means	68.19	76.25	73.86	65.66	65.50
SD	9.49	7.65	9.68	9.37	8.59

The results in table 6 show that the group that received treatment have high posttest mean scores of E_1=76.25 and E_2=73.86. Independent t-test was carried out to determine if the means cores of the pretests E_1 and C_1 are statistically significant at 0.05 α-level. Table 7 shows independent sample t-test of pretest and post tests.

Table 7: Independent Sample t-test of Pretests E_1 and C_1 Mean Scores in PCUAT Exam.

PMCAIQ	Levene's Test for Equality of Variances		t-test for Equality of Means		
	F	Sig.	T	df	Sig. (2-tailed)
Equal variances assumed	3.100	.083	1.298	71	0.199
Equal variances not assumed			1.384	69.679	0.171

Critical values t_c (71)=1.667) Calculated values t (71) =1.298, p<0.05)

The t-test value in table 7 is t (71) =1.298, p<0.05) is less than the critical value t_c (71)=1.667. The means of E_1 and C_1 were not statistically significant at 0.05 α-level. This indicates that the groups were similar initially before the treatment was administered. Although the mean scores appear to suggest that the Gowin's Vee heuristic strategy improved students' metacognition, ANOVA test was carried out to determine whether the mean difference were statistically significant at 0.05 α-level see table 8.

Table 8: Summary of One Way ANOVA of Pretests and Posttests Mean Scores obtained by the Students in PMCAIQ.

SOURCE	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	3068.338	3	1022.779	12.895	.000
Within Groups	10310.709	130	79.313		
Total	13379.047	133			

Critical values Fc (3,130=2.67, p<0.05). Calculated values F (3,130=12.895, p<0.05)

The One Way ANOVA test results in table 8 has F- ratio of F (3,130=12.895, p<0.05) which is higher than the critical value F_c (3,130=2.67, p<0.05). This implies that the effect of the Gowin's Vee heuristic strategy was statistically significant at 0.05 α-level. Therefore, the Gowin's Vee heuristic strategy was effective in improving the students' level of metacognition. However, post hoc analysis was done to have an actual comparison of the mean scores as shown in the table 9.

Table 9: Tukey's Honest Significant Difference Post Hoc Analysis for PMCAIQ Examination.

COMPARED RESULTS		MEAN DIFFERENCE	P-VALUE
Posttest E_1	Posttest E_2	2.39*	0.873
	Posttest C_1	10.59*	0.000
	Posttest C_2	10.74*	0.000
Posttest E_2	Posttest C_1	8.20*	0.001
	Posttest C_2	8.35*	0.002
Posttest C_1	Posttest C_2	0.155	1.00

*Significant at p< 0.05

The post hoc analysis results of the Tukey's honest significant difference in table 9 shows that the mean differences between posttest experimental group E_1 and all the other groups were statistically significant at 0.05 α-level. Also there was statistically significant difference between the mean differences between posttest E_2 and all the other groups except postestE_1. However it can be noted that the mean differences between the two experimental groups E_1 and E_2 were not statistically significant. This makes it possible to conclude that the improvement was due to exposure to Gowin's Vee heuristic strategy and therefore the null hypothesis can be rejected.

The metacognition constitutes planning, monitoring and evaluation skills. Planning involves actions of setting goals, budgeting and time allocation. Monitoring entails understanding of the task and self-testing. Evaluation means appraisal, checking over goals and conclusions involved in the task. Thus Metacognition enables the students to self control their own learning process by being able to plan organize and evaluate themselves. This study compared how students performed in each category of metacognitive skill as shown in the table 10.

Table 10: Overall Posttest Means Scores and Standard Deviation for Metacognitive Self Regulation Skills

Metacognitive Self regulation skill	Overall mean scores	Standard deviations
Planning	70.8831	14.15727
Monitoring	67.2687	12.84387
Evaluation	73.1940	10.60747

Figure 3 is a graphical illustration of the results in table 10.

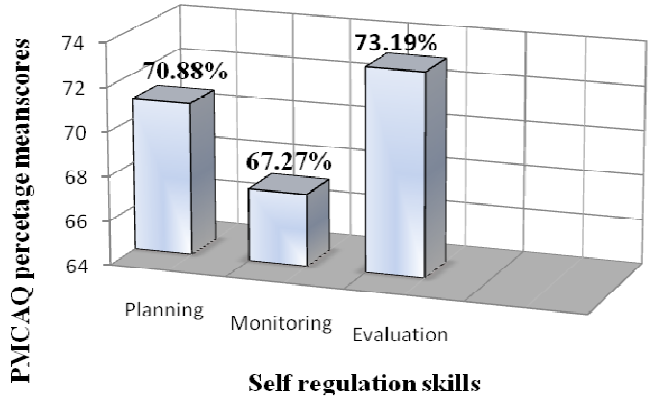

Figure 3: Graph of PMCAIQ Mean Scores against Metacognitive Self-regulation Skills.

Table 10 and figure 3 show the students overall posttest mean scores in planning, monitoring and evaluation metacognitive skills. The scores are 70.88%, 67.27% and 73.19%. This indicates that even though Gowin's Vee improves students' metacognitive self regulation skills these skills are no acquired at the same rate. The results imply that monitoring was the least improved skill. Therefore students were not aware of their weaknesses and strengths in the learning process.

The pretest values agrees with Gunstone (1994) that the learners posses some level of metacognition naturally. In addition the finding of this study agrees with Novak and Gowin (1984) who were the first to use the tool. They attribute the metacognitive ability of the tool to the structure and hierarchical nature of the tool. By going through the twelve epistemological elements of the tool the learner improves in planning, monitoring and evaluating the knowledge they are undertaking. It allows the learner to organize their cognitive structures into more powerful integrated patterns and learners examine the conceptual and rational nature of the knowledge which they are actively learning. Thiessen (1993) concur that Gowin's Vee guides the thinking process of the teacher and that of the student in the problem solving situations. It gives useful knowledge to teachers about their students thinking and values.

The result of this study is in accordance with Alvarez & Risko (2007) and Åhlberg and Ahoranta (2002) who have also established that Gowin's Vee heuristic promotes metacognition. It improves students' self -regulation and control of learning process especially when they are confronted with new knowledge. This is done by going through the twelve epistemological elements of the Gowin's Vee.

When learners build their knowledge using Gowin's Vee they develop metacognitive skills (Ramírez et al, 2008).

This is also echoed by Roth and Bowen (1993) that during laboratory experiments students organize their thinking and guide themselves in their learning process. In addition Vanhear and Pace (2008) agree that Gowin's Vee captures all the mental process involved in their thinking, acting and feelings. These motivate the learners and their performance improves. More so it makes the learner to identify their internal thinking environment. The teacher can understand what is taking place in the learners' minds. Hence they develop ideas on how they respond to various situations.

Gowin's Vee heuristic is a tool to monitor and promote metalearning and metacognition (Åhlberg, 1993). In going through the twelve epistemological elements (Vanhear, 2012) the learners become reflective and are equipped in decision making and problem solving skills. On top of these Ritchhart,Turner and Hadar (2009) implied that the use of Gowin's Vee by putting learning at the centre point of metacognition whereby learning should be developed from the related constructs like self regulation and conceptual understanding.

1.6 Conclusion

The study investigated the effects of Gowin's Vee heuristic strategy on secondary school students' conceptual understanding and metacognition in the topic of moments in physics. This was in relation to poor performance partly associated to lack of conceptual understanding. As a result, few students choose physics in form two providing less numbers of individuals with technical know how. The study specifically sought to verify the general hypothesis that there is no statistically significant difference in conceptual understanding and metacognition between students taught using Gowin's Vee and those not exposed to it, in the topic of moments in physics. The findings of this study rejected the null hypotheses and thus the Gowin's Vee heuristic strategy actually improves students' conceptual understanding and metacognition.

These findings are in agreement with previous research supporting the importance of Gowin's Vee heuristic strategy in the teaching and learning of science. Not only does it improves students' conceptual understanding and academic achievement but also promotes metacognition. Conceptual understanding makes the concepts become clear to the learner, enable the learner relate the concepts, builds a more complex interrelationship of the science knowledge, prevent rote memorization and improves performance. The knowledge is organized meaningfully in the mind of the learner.

Also metacognition enables the learner to manage their own thinking, learn some content on their own, easily study and improve their performance. The Teachers can monitor how students are learning. All these benefits are brought about by the use of the Gowin's Vee heuristic strategy. Hence it is clear that the study joins other studies in calling for the use of the tool in teaching and learning of science.

1.7 Implication of the study

This study has given rise to some important findings which are very useful to the teaching and learning in the secondary school science. The establishment in the study that Gowin's Vee improves conceptual understanding and metacognition has been supported by related studies. It was also established that Gowin's Vee has many other benefits e.g. being used in research and as laboratory report. These make it a very useful teaching tool which should be utilized.

Therefore it has implications on the teachers and students in the secondary schools to inculcate Gowin's Vee heuristic in their teaching and learning process. In other sciences and particularly, in physics lessons the students should be able to use Gowin's Vee heuristic to solve problems. This is in order to understand the structure of scientific knowledge by giving a summary of the topics using theories, principles and concepts together with the activities being used for a better scientific process and conceptual understanding.

It is an additional advantage that the Gowin's Vee heuristic strategy also improves the level of metacognition whereby the students are able to plan, monitor and evaluate their own learning process. The improvement of metacognition will not only improve the learning of physics but also other science subjects in general. Therefore this is a teaching tool whose time has come. Teachers should abandon methods that encourage rote memorization of content for passing exams only. The learning process should impart life long skills that enable the learners be able to solve day to day challenges faced in the world especially in Kenya today. This will make many learners to be self reliant and hence be self employed. Thus the science teachers and curriculum developers should consider Gowin's Vee heuristic as among the useful tools in the teaching and learning of sciences in secondary

schools.

1.8 Recommendations

The study has established that the Gowin's Vee heuristic strategy improves students' conceptual understanding and metacognition in the topic of moments. This tool has significantly proved that when it is used in classroom situation it can make the learners improve the understanding of scientific concepts principles, laws and theories through conceptual understanding and metacognition henceforth promote meaningful learning (Gowin & Novak, 1984). It is against this background that the following recommendations are made.

i. Science teachers should promote conceptual understanding through meaningful learning tool like Gowin's Vee and minimize using expository methods which promote rote memorization of content.
ii. The in-service teachers training like SMASSE in Kenya secondary schools should include and promote the use of Gowin's Vee heuristic strategy.
iii. The promotion of metacognition as an important aspect of learning should be done during the teaching and learning process in secondary schools.
iv. Schools should employ only qualified science teachers who can apply a variety of teaching approaches and strategies and not untrained teachers as is the case in some of the schools.
v. Student teacher ratio should be reduced by employing more teachers to enable active interaction between the teacher and the learner.

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