Improving Transfer of Learning through Graphical Representation

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Abstract: The use of graphs as reasoning tool in transferring content knowledge of one area to another through source processing was explored in this study. The study investigated the parameters under which beginning physics students use graphs as a tool in mediating a content area (mathematics) into another (physics). One hundred fifty-seven students were given kinematics problems. One set of problems required the active use graphical representation, the other passive graphical representation. To control for transfer effect of established knowledge, pure text problems were also administered. ANOVA was used to determine if there is a significant difference in the mean scores of the students in the three activities. Furthermore, students were given achievement tests and graphing skills test. The scores from these two tests were correlated. In general, the results showed that active representation of graph is a powerful tool in enhancing problem solving skills of students.

Keywords: source processing; graphing skills; active graphical representation

1. INTRODUCTION

1.1 Learning through graph and diagram

Innovative forms of presenting and communicating information have opened up due to multimedia learning in using graph and diagram (Mayer, 2001). The familiarity of animated pictures which rely on electronic equipment was been utilized, aside from that, other forms of multimedia learning were use before technical media were invented (Plötzner, Bodemer & Feuerlein, 2001). Since long before when computer programs started, graphs and diagrams have been constructed manually, using pencil and paper. To the fact that in the multimedia age, the use of such traditional forms of mental representation has also changed considerably (Van Merriënboer, Schuurman, Crook, & Paas, 2002). The building of certain forms of representations which allows users to mix forms of mental representation that address with different mental model were facilitated by electronic equipment (Pospiech, 2007). Information that is not suited for verbal description was presented in visual-spatial form. Before, presenting text using graph and diagram become time consuming and expensive during the time when computers is not yet popular (Kirschner, 2002). The frequency with which graph and diagram are used and encountered has been increased since computers have made the modification and construction of graphs and diagram conveniently. In the other hand, adapting the design of graph in connection to processing human information has shown successful effort (Redish, 2005). Dual information coding which is considered to be particularly useful in increasing reasoning and transfer is foster using multimedia learning environment, this allow students to use situations, concepts, and events in language in utilizing the use of graph and diagram (Stern, Aprea, & Ebner, 2003).

Diagram can be superior to non-diagram description for solving problem, one reason is that, diagram can group together all information that is used together, thus avoiding large amount of complex search for the elements needed to solve problem (Cleveland, 1995)s. Another reasons why diagram is superior to verbal is that, diagram typically use location to group information about a single element, avoiding the need to match symbolic labels (Guthrie, Weber, & Kimmerly, 1993).

1.2 The importance of graph in the study of physics

Construction a graph is considered as part of physics, many physics activities such as high-school class presentation, theoretical presentation and experimental research result utilize graph in extracting information from it (Kosslyn, 1994). This modern age provide a lot of opportunities for the students to maximize the use of graph and diagram in extracting information, presenting information, and reasoning in many of specialization. But one factor that impede the potential of graph to learning is the variety of complexity in which information is presented in graph and diagram, the result may distract learner and students who have lower levels of graphing skills that result to get lost into a wrong conclusion. Students who have low levels in graphing skills may experience difficulties in extracting vital information for the graph (Lohse, 1993). For the graph to become useful to students, it is important to engage learners in activities that allow them to construct and extract information from the graph. In connection to graphing skill learner have to become aware of how certain aspect of space can be mapped onto certain content elements (Cleveland, 1993).

Computer can be useful in creating a graph when students know the techniques and limitation it posses and once the data were plotted in the graph the students in the laboratory class still has to decide whether the results of regression analysis are physically meaningful. This method will give a clear understanding of the experiment performed in the laboratory and the true purpose of graph in the experimental study (Sha & Carpenter, 1995). The role of computer in designing graph have lessen the burden and time in constructing graph but it is also important to know the proper way of constructing graph manually using pencil and ruler, through this students ability to construct graph can be used in extracting information from the graph. Thus, the ability to plot and interpret graph properly is an essential skill that physics students should learn first in many experiments that involved plotting a graph (Kaput, 1987; Kosslyn, 1994; Mayer, 1993b; Mayer, Sims, & Tajika, 1995).

1.3 Reasons for constructing graph

Primarily, we plot a graph to obtain an overview of the data. According to Ainsworth, Bibby, & Wood (2002), a clear overview on the graph reveals several things that might not be obvious from a table of data alone. One reasons graph is created is to know how does a change in one variable lead to a change in the other. Variables plotted in the graph can be either increase or decreases due to the other variable or in some cases variable plotted will not show necessarily straight-line trends. Changes in the variables are due to the physical law set in the graph, the data and information obtained from the experiments using a set of equations and formula is presented in table which can be converted into graph. An example is the computation of the electric force exerted by two charge body as the distance varies. Obviously, the result will show a decrease in the force magnitude when distance between the two charges increases. With the help of graph other patterns different from the expected outcomes can be easily observe and appropriate analysis and interpretation will give answer to the problem. Thus plotting graph will allow students to observe if there is no correlation between the plotted quantities which can be considered as one important result in the experiments. This can occur if students plot wrong variables or even perform the wrong experiments.

Constructing graph will also help students to determined if data are sufficient since the points visible from the graph can be completely analyze well if the range of data from the set of quantities are complete. Thus it is important to let students set how many data point they will be setting to allow them to maximize the use of graph in sourcing information. During the analysis of graph, a region of interest that suggests further analysis must be considered. Experiment using computer aided device that measures the position of a falling object that depend on time can be trace using the graph printed on the screen of the computer and a change on the appearance of the graph will help students determine factors that affected the result, these factors could be due to friction from the gases or due to the friction on the pulley. A change on the slope of the line will provide clear view on how certain objects follow the physical law (Deacons, 1999).

1.4 Source Processing

In the study of physics and mathematics the concept and principle involve in the study can be fuse using graph and diagram to create a better and realistic application into a real life (Bétrancourt, & Tversky, 2000). To attain this, two aspects such as verbal description and mathematical formula describing the central law should be bridge using graph and diagram to attained better understanding of a subject (Cox, & Brna, 1995). The mathematical formulas that model the essential laws of physics are no more complicated than elementary school mathematics. For example, Newton's laws of mechanics require only the multiplication and division of numbers(Kozma & Russell, 1997). Despite the simplicity of such mathematical models, learners lacking a deeper understanding of the underlying concept often have no idea of how, why, and in which order equations have to be applied in the problem solving (Stern, Apprea, & Ebner, 2003).

2. METHODOLOGY

2.1 Participants

The participant of the study are forty-one students attending vocational education program in apparel and fashion (14 male, 27 female, the mean age is 18.3 years old, and the standard deviation is 2.4), 40 students in industrial art education (12 male, 28 female, the mean age is 17.9 years old, and the standard deviation is 2.1), 39 students in computer science (18 male, 21 female, the mean age is 18.7 years old, and the standard deviation is 1.9), and 37 students in electrical engineering (23 male, 14 female, the mean age is 17.9 years old, and the standard deviation is 1.7). These four groups of students were participated in the study.

2.2 Procedure

Participants were randomly assigned to three conditions of graph activities, for which they were given 40 minutes. To control, students had actually read the source text, they were asked to answer questions presented at the end of the text. During the experiments, the mean amount of time required for active performance in the graph activities was the same in all three groups. Immediately after the 40 minutes had elapse, all subjects were presented with graphing skills test and subject content test. All participants were instructed that drawing might help them to answer the question, and they were provided with graphing paper, pencils, rulers, and erasers. The time set for the graphing skill test is 40 minutes and the set time for subject content test is 30 minutes.

3. RESULT AND DISCUSSION

3.1 Active graph representation

The result of the graphing skill test, after students were subjected into active construction of graph is shown in the table 1. The comparison is reflected by the mean score gained in the test while the standard deviation indicates how individual scores is scattered. The highest mean frequency was attained by the engineering students (34.31), the second mean scores was attained by the computer science students (30.57), the third mean score was attained by students in education (15.35), while the least mean scores was attained by vocational students (14.73). Base on the data it was observed that active graphical representation is useful for engineering students but contrary to the old belief not to the vocational and art education students.

Table 1. Mean score and the standard deviation in the active graph representation

Course	Mean	Standard deviation	N
Engineering	34.31	6.135	39
Computer science	30.57	5.279	37
Industrial art edu'	15.35	4.693	40
Vocational	14.73	2.992	41
Total	23.48	10.084	157

The highest standard deviation (6.135) was attained by the engineering students the high standard deviation indicates that most of the scores have higher distance with the average scores attained in the test which might be due to individual differences in processing graph. The low standard deviation (2.992) attained by the vocational students indicate common similarity on students technique in dealing with graph. The low standard deviation shows homogeneity of the scores.

3.2 Passive representation of graph

An activity that introduced different topic in kinematics that introduce concept about motion was introduce in the class. This activity limit the student to construct graph actively in which graph is not included in the activity. Instead a constructed graph was presented to the students followed by a question that will measure its effects through scores. To determine how students responded through a condition in which there is no active construction of graph the mean scores and the standard deviation of the four courses were compared. Table below showed that the highest mean scores was obtained by the students in engineering (30.33), the second mean score was obtained by the students in computer science (28.11), the third mean scores was obtained by the students in art education (18.08), while the least is the mean score of vocational students (13.24). The highest mean score obtained by the in engineering students might be due to their strong foundation in the said subject matter and mostly credit lot of subject in science and mathematics while those group of students who gained less in the mean score credit small subject in science and mathematics as a requirement for their course.

Table 2. Mean score and the standard deviation in the passive presentation of graph

Course	Mean	Standard deviation	N
Engineering	30.33	5.278	39
Computer science	28.11	3.657	37
Industrial art education	18.08	4.079	40
Vocational	13.24	3.137	41
Total	22.22	8.174	157

Among the four group the highest standard deviation (5.278) was obtained by the students in engineering which indicate a far distance of individual scores to the mean scores and this might be due to differences in how students process knowledge during the activity, in the other hand, the low standard deviation obtained by the students in education (18.08) and vocational (13.24) show a homogeneity on the scores.

3.3 Textual content without active graph & presentation of graphs

The control in this experiment was done using a pure textual content that contain the same topic in kinematics but do not include active construction of graph nor present a graph in the content explanation. The method used in the analysis of this result was the same with the method used in the two condition presented earlier. The high means score of the students in engineering (24.82) predict the processing ability of the student and the content knowledge they used to process the textual content presented to them. It was followed by the mean scores of the students in computer science (22.57) which could also related to the ability of the students to process concept, then followed by the mean scores of the students in education (16.85), and lastly, the least among the group is the mean scores of the students in vocational (17.24). According to Schnotz (2004), the ability of the students to process information in the graph is strongly related to the ability of the students to process conceptual understanding.

Table 3. Mean score and the standard deviation in the passive presentation of graph

Course	Mean	Standard deviation	N
Engineering	24.82	4.773	39
Computer science	22.57	5.091	37
Industrial art educ.	16.85	4.753	40
Vocational	17.24	3.137	41
Total	20.28	5.616	157

The heterogeneity of the scores is reflected on the standard deviation on the scores of the students in engineering, the result of the mean score can be correlated to the standard deviation of the said students. The result indicate that a high standard deviation of the said students predict the heterogeneity of the scores of the students and the uniqueness of individual thinking ability of the students affect the result of the mean scores, in the other hand the low standard deviation of the students in education and vocational is also related to the result of the mean scores of the students, thus the homogeneity of the scores show common thinking ability among the students which resulted to a low standard deviation.

3.4 Comparison on the three condition of activity

The participants of the study were experimented into three conditions to determine how students use graph as a source text in transfer of knowledge in the graphing skills test. In the first set of activity, the active graph representation were utilize in the activity then evaluated using the graphing skills test. On the second stage of the experiment, an activity using a concept source was introduced to all the four groups but without active representation of graph (passive graph), then evaluated again for its effect using the graphing skills test. In the final stage of the activity a text that don't include active presentation of graph were experimented to the students and this serve as a control variable in the experiment. To distinguish how the three stages of activity affect the performance of the students in the experiment the mean scores of the students obtained from the graphing skills test were presented and compared in the table below.

Table 4. Mean scores in the three conditions

Activity	Mean	Standard Error
Active Graph	23.739	0.36
Passive Graph	22.440	0.36
Control	20.370	0.36

The activity that gained the highest mean scores was the activity that include construction and extraction of graph in the experiment gained a mean score of 23.739, this activity include active graphical representation which is integrated in the source text. The activity that presents graphical representation without active construction of graph gained a mean score of 22.440. In the other hand, the activity which serve as a control present only a text that do not include presentation of graph nor active construction that gained a mean score of 20.370 which is the least among the three activity. According to Carey (2001), student's ability to process information from the textual form is related to the ability of the students to integrate pre conceptual content. Although, students gained more in the activity that utilize active construction of graph in the experiment, the scores gained by the students in using a text as source of information has a higher capacity to improve if proper design for instruction can be presented.

3.5 Comparison of the four different courses in the experiment

Four different courses were chosen to determine how they utilize active graphing representation in graphing skill test and topic content test, the test that evaluate how students acquired conceptual change or how students organized prior knowledge to construct a more precise solution to the problem were evaluated using the content test which was been constructed before the experiment were presented to the students. In connection with the main objective of the study, four courses were chosen with different field of study and specialization so that the comparison and differentiation to which group of student utilized graph in solving problem in physics. These four courses were categorized into the group of students who have strong background in science and mathematics and mostly uses graph in the study of their courses, these two courses that have strong background in science and mathematics and credit high number of subject to it are the engineering students and the students in computer science. In the other hand the two courses which their field of specialization do not focus in science and mathematics but more on art and social education are categorized as the group of students whose background in science and mathematics is not that strong enough and do not usually use graph in the field of study, these two courses are the art education students and the vocational students in fashion and apparel. The comparison of the four courses were summarize in the table below.

Table 5. Comparison of the mean scores of the four courses

Courses	Mean	Standard error
Engineering	29.821	0.416
Computer science	27.081	0.427
Art education	16.758	0.411
Vocational	15.073	0.406

The univariate general linear model computation was done to compare the mean of the four courses, and base on the result, those students who gained the highest mean score is the course in engineering (29.821), followed by the mean score of the students in computer science (27.081) and art education (16.758), the least mean scores was obtained by the vocational students (15.073). According to Duit (2003), the students ability to process knowledge in problem solving is related to the prior ability of the students acquired from the earlier study or to their exposure to a certain particular knowledge and it was stated in the study that those student who have strong exposure in the study of science and mathematics gained the highest mean scores as the result of the activity presented to them, in the other hand, those students who have a small experience and exposure to science and mathematics gained the least mean scores in the graphing skills test and content test.

3.6 Pearson r Correlation

The used of graph to process information become very effective if it is guided with proper representation such as text and pictorial that will link and help the students to form analogy and solution to many problem or answer to many questions. This technique of linking pictorial representation with textual representation which is the essential part of the graph will improve the graphing skill of the students (Schnotz &Bannert, 2003). It was also found out from that active graphical representation that increase student's skill to process new concept to solved problem thus to prove the assumption, a score gained by the students in the achievement test must be correlated with the graphing skill scores of the students.

To determine the role of incorporating active graphical representation on the performance of the students in physics, the graphing skills scores and the achievement test scores were compare using the linear regression. Studies found out that students' ability to construct and analyze graph is moderately correlated to the ability of the students to solve problem in physics (Stern, Aprea, & Ebner, 2003). The entered variable is the scores of the engineering students in the graphing skills test and the achievement test.

Table 6. Mean and standard deviation of the scores in the graphing skills and the achievement test

Descriptive statistics	Mean	Standard deviation	N
Achievement scores	28.50	6.69	157
Graphing skill scores	23.48	10.08	157

The mean scores in the achievement test and graphing skills test of the students who undergo active construction of graph are 28.50 and 23.48. While the standard deviation of the achievement test and graphing skill test are 6.69 and 10.08. Although the mean scores of the two tests are near to each other the standard deviation of the graphing skill is higher than the standard deviation of the achievement test which indicates that the scores in the graphing skills are more homogenous compare to the achievement test. Studies found out that students' ability to construct graph and analyze graph is related to the ability of the students to solve problem and apply it to real life situation (Stern, Aprea, & Ebner, 2003). The entered variable is the scores of the engineering students in the graphing skills test and the achievement test.

Table 7 Pearson correlation of the achievement test scores and the graphing skills scores

Correlations		ATS	GSTS
Pearson Correlation	ATS	1.00	0.353
	GSTS	0.353	1.00
Sig (1-tailed)	ATS		$p \leqq 0.05$
	GSTS	$p \leqq 0.05$	
N	ATS	157	157
	GSTS	157	157

Note: ATS (Achievement test scores), GSTS (Graphing skill test scores)

Statistically, the Pearson-r correlation was utilized to determine the relationship between achievement test scores and the graphing skills scores. The computed value of r (0.353) indicates a moderate correlation between the two sets of scores. Since the information and skills gained from the graphing skills through active construction and extraction of graph were utilized in testing, highly correlation indicates a strong correlation between the two variables while a low correlation indicates a weak correlation between the two variables, in the other hand the two set of variable were significant at .05 level of significant based on the two tailed test of comparison between the means score of the graphing skill test and the mean score of the achievement test in the total 157 participant used in the experiments. The square of the computed Pearson correlation is 0.124 were multiplied to one-hundred, this will identify the percent of the total population used in the study that explain the scores in the graphing skills test predict the scores in the achievement test. Thus 12% of the total sample can explain that the scores in the graphing skill test predict the scores in the achievement test.

The standard error which is 6.28 indicates the distance between the estimated scores to the actual scores, thus greater distance between estimated scores and the actual score indicates a higher standard error while a lesser distance indicates a smaller standard error.

The linear equation $y = mx + b$ was utilized in the linear regression, the value of y-intercept (y=23) in the regression line show that, student attained a score of 23 in the achievement test when the students attained zero in the graphing skill test. The value of the slope (=0.23) is the constant value which is 0.23, this indicate that in every one point gained in the graphing skills test, the scores of the students in the achievement test will increase into 0.23. The standard error for y-intercept (1.27) is higher than the standard error of slope (0.05) which indicates a higher distance of actual score to the estimated scores.

Table 8. slope and the y-intercept

Model	B	Standard Error	t	Sig
Constant	23.0	1.27	18.04	$p \leqq 0.05$
GSTS	0.23	0.05	4.69	$p \leqq 0.05$

Note: GSTS (graphing skills test scores), SE (Standard error).

The frequency and the regression standardized residual were plotted, were in, the mean of the regression standardized residual is set into zero while the standard deviation were set into 1, the structured of the graph give emphasis on the moderate correlation between the scores in the graphing skills and the scores in the achievement test.

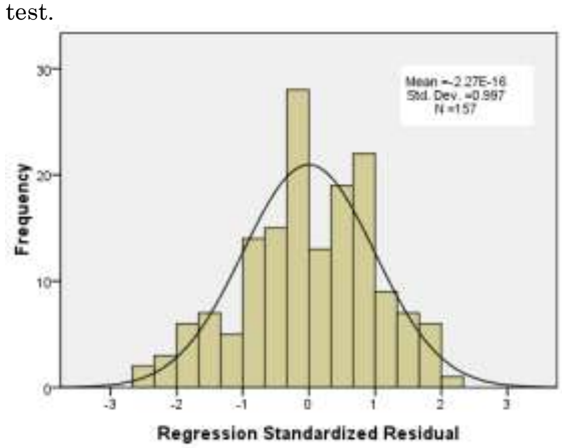

Fig. 1. Frequency and regression standardized residual

The linear correlation were presented in the regression standardized residual and regression standardized predictive value in the plot were we can see the small variation on the student who gained in the graphing skill but did not gained in the achievement test, the same also with the other side-part of the graph which show a small variation on the students who gain in the achievement test but did not gained high in the graphing skill test. At the middle, there are higher number of dots which best explain the relationship between the two variables.

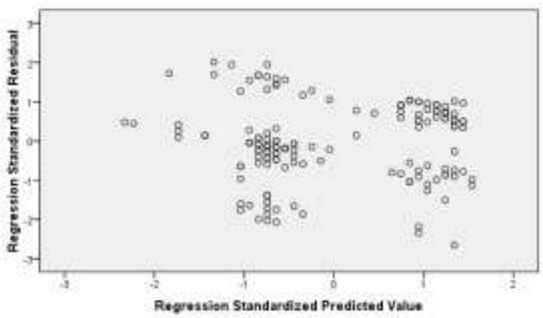

Fig. 2. RSR and the RSP graph

At the middle, there are higher number of dots which best explain the relationship between the two variables which was been indicated by table 7. To all that were said and done, active graphical representation is a tool for data analysis and better understanding in physics. Like many tools, its effectiveness is only as good as the proficiency of the user. A competent student should be able to draw and interpret a graph if it active graphical representation was properly introduce to the students. On the other hand, top-quality software and high-speed computers are no guarantee that a useful result will be obtained if the reasons for drawing the graph are not understood. Thus active graphical representation provides a bridge between the two disciplines, since it provides a convenient way of visualizing the mathematics and the physics together.

4. CONCLUSION

The problem stated earlier were answered in the analysis section, and the result from the computation show that active construction of graph can play an important role in fostering source processing in solving problem in physics. The substantial correlations between the graphing skills test and the achievement test in the study suggest that cognitive processes prompted by graph construction go beyond unspecific effect of cognitive activation. The correlations are in line with the assumption that, by active graphical representation, learners may become aware of the element of the graph in which it is vital and significant in mapping information.

Despite of its effectiveness in improving activation of cognitive activity of the students, integrating active graphical representation to the class must be modified to a certain extent. The study revealed that learners with high background in science and mathematics benefited more from active graphical representation than from the students who passively encountered the graph. The study also revealed that those students who gains in active graphical representation but not that high with the students with strong background in science and mathematics may also profit from active graphical representation if they are provided with appropriate opportunities for practice and given some hint in graphing activity. In connection to this, future research in maximizing the use of graph in learning environment are required to indentify and determine what kinds of graphical activities that are most applicable with regard with the cognitive ability of the students.

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