Birlesik Dünya Arastırma BD-CENTER Innovasyon ve Yayıncılık Merkezi

Cypriot Journal of Educational Sciences

Volume 15, Issue 4, (2020) 843 - 853

www.cjes.eu

Improving students graphing skills and conceptual understanding using explicit Graphical Physics Instructions

Michael Allan A. Bahtaji [a]*, University Research and Development Services, Technological University of the Philippines, Ayala Boulevard, Ermita, Manila 1000, Philippines https://orcid.org/0000-0003-4117-9185

Suggested Citation:

Bahtaji, M. A. A. (2020). Improving students graphing skills and conceptual understanding using explicit Graphical Physics Instructions. *Cypriot Journal of Educational Science*. *15*(4), 843-853. https://doi.org/10.18844/cjes.v15i4.5063

Received from April 1, 2020; revised from June 23, 2020; accepted from August 24, 2020.

Abstract

The study presented investigates the effects of supportive graphical interventions on the graphing skills and conceptual understanding of students in physics. In this study, the first group of participants was presented with ready-made graphs during the instruction, the second group was instructed on the proper construction and extraction of graphs, while the third group was instructed to construct graphs independently. The groups were compared with respect to their scores in the graphing skills and achievement tests before and after the instructions. The group that received supportive intervention in construction and extraction of graphs attained the highest number of high-level graphs constructed and obtained the highest increase in the achievement test scores after the instruction. The results revealed that the use of the supportive graphical intervention in the construction and extraction of graphs improved the graphing skills and conceptual understanding of students, especially for those who experienced difficulties in dealing graphs.

Keywords: Graphical interventions, construction of graph, interpretation of graph, graphing skills, conceptual understanding;

*ADDRESS FOR CORRESPONDENCE: Michael Allan A. Bahtaji, Technological University of the Philippines, Manila 1000, Philippines
E-mail address: michaelbahtaji@gmail.com/ Tel.: +623-8301-3001 loc 711

1. Introduction

Skills in reading and interpreting graphs are essential in physics teaching and learning, as well as in everyday life. This is because, all information presented in the internet, newspaper and televisions are often depicted using graphs. Processes involved in construction and extraction of graphs play an essential role in the development of new knowledge, as the processes involved promotes the learners' ability to develop new knowledge (Duijzer, Van den Heuvel-Panhuizen, Veldhuis & Doorman, 2019). Graphs are used in interpreting data. They can reveal new patterns and relationships which cannot or difficult to see in a row of data. Graphs are very essential because scientists use graphs to communicate information and to validate the depth of their claims. However, despite of the importance of graphing skills in learning development and in everyday life, it has been observed that learners, whether novice or expert learners, are experiencing difficulties in constructing and interpreting graphs (Bollen, van Kampen, Baily, Kelly & De Cock, 2017; Glazer, 2011). Measurements in the graphing skills of students revealed weaknesses and difficulties in terms of graphical comprehension which include difficulties in identifying variables, relating variables, choosing the appropriate graph for a certain range of data, analysing pattern, and presentation of data using graphs (Glazer, 2011; Stefanel, 2019; Taylor 2010). Students' difficulty in dealing with graphs was associated also to prior content knowledge and graphing skills, whereas students who have insufficient content knowledge and graphing skills often encounter difficulties in seeing the context graphs intend to depict. For example, in the study conducted by Phage, Lemmer and Hitge (2017) using 152 first year undergraduate physics students, they found that students' deficiency in contextual knowledge hamper them to identify inferential processes needed in reading graphs. Thus, to lessen the negative effects of students' lacking skills in dealing with graphs, explicit graphical interventions could be integrated in physics teaching to help students identify graphical representations useful in graphical interpretation. In the pre-test-post-test study done by Harsh and Schmitt-Harsh (2016), they found that explicit instruction in construction and extraction of graphs significantly improved the graphing skills and attitude of college students in graphs. Teaching intervention on how to extract information from graphs and on how to interpret distance between two data points activate students' higher order thinking skills that include critical thinking, problem solving and creativity. Graphing skill was also associated with lab activities that incorporate active constructions and extractions of graphs, whereas learners who were engaged in the said activity gained substantial learning in lab works and grasp deeper understanding in using graphs (Meisadewi, Anggraeni & Supriatno, 2017). Given the significant contribution of explicit graphical interventions on the graphing skills of the students, studies that explore the effects of these interventions to both graphing skills and conceptual understanding – as both were regarded as important in learning – seems to be inadequate and missing. To respond to this gap, this study has investigated the effects of supportive graphical interventions on the graphing skills and conceptual understanding of undergraduate students in physics.

1.1. Extraction of graphs

The process of acquiring information from graphical representations involves the process of reading and identification. Studies Shows that the ability of students to interpret graphs coordinates is related to their ability to assign variables in graphs (Remziye Ergül, 2018; Nixon, Godfrey, Mayhew & Wiegert, 2016). Assigning variables in graphs, which include identification of variables, are important in reading and interpreting graphs, since the ability to assign variables in graphs during graph construction is related to the ability to extract information from graphs. Assigning variables in the axes of graphs are not considered as a very complex task, since the independent variables are conventionally assigned to x-axis while the dependent variables are assigned to y-axis (Taylor, 2010). In case of multiple dependent variables, understanding the label of individual lines and assigned legends are important in extracting information from graphs (Dart & Radley, 2018). The process involves identification of the symbols represented by different colours or identification of lines that represent best-fit line of the graph. Effective reading and interpretation of graphs require prior content knowledge in construction and extraction of graphs. Prior knowledge in graphs includes skills in sketching line chart abscissa, ordinates, and scales. Skills in interpreting graphical structures, which include identification of elements presented in graphs, are also important in reading and interpreting graphs (Phage et al., 2017). It has been argued that proper identification of graphs or interpretation of graphs does not directly start with the process of reading, but instead, identification of graphical representations usually begins with the understanding graphical structure (Glazer, 2011). This indicates that knowing the structure of graphs is very important in extracting information from graphs. Whereas, the understanding effect of the graph is greatly related to the visual information on the graph. For example, the ascending line indicates an increase in the value of the variables, which means 'more and more'. This suggests that effective learning and understanding happen when all the graphical components were identified and processed which can be interpreted based on the steps and procedures used during a graphical analysis (Dart & Radley, 2018; Nixon et al, 2016).

1.2. Construction of graph

Although graphical interpretations are common in studying, especially in the field of natural science, active construction of graphs is seldom carried out independently in the classroom settings. It has been observed that active constructions of graphs can serve as the centre of the learning activity in which the process of comparing and distinguishing graphical variables becomes effective compared to the non-active construction of graphs (Harsh & Schmitt-Harsh, 2016; Nixon et al., 2016). Based on the study pertaining to the active construction of graphs, it turns out that active construction of graphs has a significant beneficial effect on the learning development of a student (Meisadewi et al., 2017; Stern, Aprea & Ebner, 2003). In this study, the importance of instructions in active construction and extraction of graphs, was explored and evaluated. To verify the effect of the above-mentioned task, this study has focused on the effects of active construction of graph to learning, specifically in the field of physics. Choosing the appropriate type graphs is important in improving students' graphical comprehensions (Stefanel, 2019; Slutsky, 2014). Presenting the proper steps in constructing and extracting graphs can contribute to the improvement in students' problem solving and critical thinking skills (Duijzer et al., 2019; Stefanel, 2019). Studies argued that mistake in estimating scales in the axes graphs was the most common mistake students usually encounter in constructing graphs (Angra & Gardner, 2017; Glazer, 2011; Stern et al., 2003). This mistake happens when the scale entered in the axes are not in series or in order, as if the data seems to appear categorical rather than arrange in intervals.

1.3. Integration of construction and extraction of the graph

Graphs are often used in teaching because they are considered as a good source of knowledge and information (Glazer, 2011; Taylor, 2010; Opfermann, Schmeck & Fischer, 2017). However, passive presentations of graphs are inadequate, whereas knowledge in constructing and designing graphs are also essential in graphical learning and comprehension (Harsh & Schmitt-Harsh, 2016; Stern et al., 2003; Taylor 2010). In a usual condition, learning materials and other sources of information are commonly prepared in two forms: text and diagrams. The usual utilizations of these two main sources of information can promote the process of accommodation and assimilation, which then result to a much deeper understanding of concepts (Gates, 2018). Students' knowledge about the subject or students' conceptual understanding about the domain develop when text and other graphical representations from graphs are linked and connected properly (Schnotz & Bannert, 2003). In this condition, the information extracted from graphs could be used to understand other information that might be extracted from the graph. Information extracted from the graph could be integrated with the other graphical components to generate further ideas that are useful to the reader of the graph (Glazer, 2011; Stefanel, 2019). These processes, which happens during graphical analysis, are very useful in understanding how students interpret graphs, which could serve as a basis in developing frameworks in understanding how students extract information from graphs. The processes used by the students in graphical interpretation are also analogous to the processes used by the students in solving scientific problems in physics and chemistry. The structural framework in constructing and extracting graphs could be viewed inductively from the test and picture comprehension model proposed by Schnotz and Bannert (2003). The integration between text and other graphical representations has been studied by mapping the spatial relationship among the components of the graph (Lin & Chiu, 2017). It has been articulated that the role of text in understanding propositional mental representation is important during graphical analysis (Schnotz & Bannert, 2003). The use of graph facilitates units in the memory to form text-based information similar to the process carried out by the memory in processing sentences while speaking the language. When processing information from graphs, the information from the statement derived from the graph is called a mental proposition. The statement "as the temperature increases the pressure increases" is an example of a propositional statement derived from graphical analysis. During graphical analysis, mental models stored from the mind of the students are utilised in order to come up with new mental propositional (Lin & Chiu, 2017; Schnotz & Bannert, 2003). These mental propositions developed during graphical analysis become useful when the answer to a certain question or problem is answered.

1.4. Structural model in dealing with graphs

Angra and Gardner (2016) articulated a framework that described the process of how students construct graphs and extract information from graphs. The framework includes cognitive skills that students consider when dealing with graphs, which includes analysis, integration, and design purpose. These cognitive skills are important in the learning development which contributes greatly in answering students' problems in class. The developed framework associates the process of the active construction of graphs to the process of interpreting graphs. The process of graphical analysis involves reading and identification. The relationships among graphical representations (ranges used, assigned variables in axes and symbols assigned to rows) are important in graphical analysis. Table 1 shows the processes that students utilised when constructing and analysing graphs.

Table 1. Processes in dealing with graphs

Construction of graphs	*Extraction of graphs*
• *Sketching the axis (x, y and z) of the graph*	• *Read and recognise the relationship shown*
• *Assigning variables to their corresponding axis*	• *Identify the axis variables*
• *Labelling the axis properly*	• *Recognise symbols and variables of the data series*
• *Sketching the legend properly*	• *Read the range of the graph*
• *Assigning the scale in each axis*	• *Read the assigned scales*
• *Entering of scores or Cartesian point*	• *Analyse the score properly*
• *Connecting the points using line*	• *Compare multiple values properly*
• *Adding multiple values to the graph*	• *Construct statement about it*

The ability of students to process information from graphs is associated with the purpose of reading the graph or the question that needs to be answered using the graph. However, proceeding immediately in reading a graph without considering all individual data points indicated on the graph may result in misinterpretation and confusion. Looking at the individual data point means that students can identify the relationships among variables present in the graph. The relationship may show how the degrees of one variable influence the degrees of another variable and how connections can be applied in the physical concepts or in actual situations (Nixon et al., 2016). The capability of the students to link variables to one another using graphical representation could be enhanced if their skills in constructing and extracting of graphs are enhanced. Assigning students to activities that involved active construction of graphs makes them aware of the variables present in the graph. This will allow the learner to become aware of the importance of graphs in their activities of daily life and will help them realise the use of graphs in the physical concepts.

2. Methodology

2.1. Participants

The participants are composed of three classes of first-year undergraduate students enrolled in introductory physics course. Each class was assigned to an intervention. One class was assigned to an intervention that utilized ready-made graphs in the physics instruction, another class was assigned to an intervention that integrate construction and extraction of graphs in the instruction, and another class was assigned to an intervention that integrate activities in active construction and extraction of graphs. In the first intervention, ready-made graphs were presented to the students without active construction of graphs. In the second and third interventions, active construction of graphs and extractions of graphs were included in the instructions. Among the 110 undergraduate students who participated in the study, 39 received the first intervention, 34 received the second intervention, and 34 received the third one.

2.2. Instrument

To evaluate the conceptual understanding of students in force and motion, the researcher developed a 50 items multiple-choice questionnaire in force and motion. Each question was constructed based on the table of specifications developed by the researcher. The initial number of items drafted was 60, which was reduced to 50 items based on the recommendations and suggestions of the experts who evaluated the questionnaire (two experienced physics teachers in the undergraduate level). To measure the graphing skill of the students, the researcher constructed a five-items graphing skill test. Each item in the graphing skill test contains questions and data that students need to answer and graph. The graphing skill test measures the graphing skill of the students specifically in Newtonian mechanics. A rubric was also developed to score the graphs constructed by the students. The said rubric has helped the researcher in identifying if the graphs constructed by the students is classified as high-level or low-level graphs. Both the graphing skill test and the rubric were also evaluated by two experts who have experience in physics teaching in the college level.

2.3. Data collection procedure

In the first phase of the study, the conceptual understanding and the graphing skills of the students in the three groups were evaluated using the concept test and the graphing skill test in physics. The intervention took place in the second phase of the study. Each class was exposed to the intervention assigned to them. The class that was assigned to the first graphical intervention was shown with graphs during the instruction (this class was named as group A in this study). The class that was assigned to the second graphical intervention was presented with the proper construction and extraction of graphs during the instruction (this class was named as group B in this study). The third class that was assigned to the third graphical intervention was tasked to do activities in constructing and interpreting graphs (this class was named as group C). After the intervention took place, the conceptual understanding and the graphing skill of the students in force and motion were re-evaluated again in the third phase of the study. All the graphs constructed before and after the experiments were classified, the levels of graphing skills were identified using the suggested rubric. Similarly, the scores of the participants in the concept test before and after the instructions were computed. The scores obtained by the participants before and after the instruction were compared. *t*-test was computed to determine whether these scores were significantly different from each other. Analysis of variance (ANOVA) was also computed to know whether the scores obtained by the three groups were significantly different from each other.

3. Results

3.1. Results on the construction of graphs

The results of the experiment are presented in this section. The mean frequencies of low-level graphs and high-level graphs constructed by the students were presented in Table 2. The number of students and the percentage of students who constructed high-level graphs and low-level graphs for both pre-test and post-test were also presented in Table 2. The number of students who constructed low-level graphs was always higher than the number of students who constructed high-level graphs among the three groups. These results were based on the scores they obtained in the graphing skills test. Similarly, all the students in the three groups have constructed low-level graphs. The percentage of students who constructed low-level graphs was 100% for all the three groups as indicated in Table 2.

Table 2. *Frequencies of students who constructed low-level and high-level graphs*

		Group A		Group B		Group C	
	No. of students	39		37		34	
	Category	LV	HL	LV	HL	LV	HL
Pre-test	No. of students w/ constructed graph	39	32	37	32	34	26
	% of the of students w/ constructed graph	100	82	100	87	100	77
	No. of expected graph	5	5	5	5	5	5
	Mean frequency of constructed graph	3.23	1.26	3.19	1.24	3.21	1.29
Post-test	No. of students w/ constructed graph	39	34	37	35	34	28
	% of the of students w/ constructed graph	100	87	100	95	100	82
	No. of expected graph	5	5	5	5	5	5
	Mean frequency of constructed graph	3.18	1.31	3.16	1.97	3.17	1.56

Note: LV = Low-level Graph, HV = High-level Graph

The mean frequencies of high-level graphs constructed by the students in the pre-test and post-test graphing skill test were presented in Table 3. Result revealed a significant change in the number of high-level graphs constructed by the students in Group B before and after the instructions. Moreover, a non-significant change in the number of high-level graphs constructed by the participants in Group A and Group C has been also observed. This indicates that the gain in score of the students who received passive presentations and graphs and independent construction of graphs is not statistically significant.

Table 3. *Mean frequencies of high-level graphs constructed by the students*

Group	Pre-test		Post-test		*n*	*t*-value
	MF	*SD*	*MF*	*SD*		
Group A	1.26	0.79	1.31	0.92	39	0.279
Group B	1.24	0.83	1.97	0.76	37	3.402*
Group C	1.29	1.00	1.56	0.86	34	1.200
Overall Total	15.47	0.86	1.61	0.89	110	2.860

M = Mean frequency, *SD* = Standard Deviation, *n* = number of participants, * = p < 0.05, ** = p < 0.01

The mean-frequencies of high-level graphs constructed by the three groups were analysed using ANOVA. A significant main effect of graphical interventions has been observed after the instructions ($F = 5.875$, $p < 0.05$). Results also revealed a non-significant difference on the number of high-level graphs constructed by the students in the three groups before the interventions ($F = 0.032$, $p > 0.05$).

Table 4. *ANOVA in the mean frequencies of high-level graphs of the three groups*

	Source of variation	*SS*	*df*	*MS*	*F*	*p-value*	*Remark*
Pre-test	Treatment	0.049	2	0.025	0.032	0.968	Non-significant
	Within groups	81.306	107	0.760			
	Total	81.355	109				
Post-test	Treatment	8.528	2	4.264	5.875	0.004	Significant
	Within groups	77.663	107	0.726			
	Total	86.191	109				

SS = sum of the square, *df* = degrees of freedom, *MS* = mean square, *F* = computed *F*-value

Using the Tukey HSD *post-hoc* pairwise comparison, the significant difference among the pairs were computed. The level of significance was set to 0.05 level, whereas, a *p*-value lower than 0.05 was considered statistically significant, while a *p*-value higher than 0.05 was considered as statistically non-significant. Among the pairs, only pairs 'A and B' and 'B and C' have shown a significant difference in the number of high-level graphs constructed (Table 5).

Table 5. *Comparison between the mean frequencies of the three groups*

Groups	Pre-test			Post-test		
	Group A	Group B	Group C	Group A	Group B	Group C
Group A	…	p > 0.05	p > 0.05	…	p < 0.05	p > 0.05
Group B	…	…	p > 0.05	…	…	p < 0.05
Group C	…	…	…	…	…	…

3.2. Results of concept test in mechanics

To determine how the graphical interventions affected students' conceptual understanding in Newtonian mechanics, the mean score and the standard deviation gained by the students using the developed test in force and motion were tallied in Table 6. The pre-test and post-test mean scores were compared. To determine the significant differences between the pre-test and the post-test mean scores, *t*-test was computed. For three groups, significant change in the mean scores of the students has been observed before and after the instruction.

Table 6. *Mean scores and standard deviation of the students in the concept test*

Group	Pre-test		Post-test		*n*	*t*-value
	M	*SD*	*M*	*SD*		
Group A	15.13	3.22	30.49	6.40	39	13.66**
Group B	16.14	2.73	36.11	5.77	37	25.82**
Group C	15.15	2.76	32.15	4.83	34	17.68**
Overall Total	15.47	2.90	32.91	5.67	110	19.05**

M = Mean-score, *SD* = Standard Deviation, *n* = number of participants, * = p < 0.05, ** = p < 0.01

Furthermore, the mean scores among the three groups were compared. ANOVA was computed to determine the significant differences between the mean scores of the three groups. The *F*-value for the pre-test ($F = 1.575$, $p > 0.05$) revealed non-significant differences between the mean scores of the three groups of students. The *F*-value for post-test ($F = 13.10$, $p < 0.01$) revealed a significant difference between the post-test mean scores of the students.

Table 7. *ANOVA of the mean scores of the three groups in concept test*

	Source of variation	*SS*	*df*	*MS*	*F*	*p-value*	*Remark*
Pre-test	Treatment	24.470	2	12.235	1.575	0.212	Non-significant
	Within groups	830.948	107	7.766			
	Total	855.418	109				
Post-test	Treatment	627.12	2	313.56	13.10	0.000	Significant
	Within groups	2561.58	107	23.94			
	Total	3188.70	109				

SS = sum of the square, *df* = degrees of freedom, *MS* = mean square, *F* = computed *F*-value

To determine the differences between the three groups of participants, Tukey's HSD *post-hoc* pairwise comparison test was conducted. The multiple comparisons between the three groups (for both the pre-test and post-test) are shown in Table 8. The level of significance was set at 0.05 level, whereas, a *p*-value higher than 0.05 was considered statistically non-significant and a *p*-value lower than 0.05 was considered as significant. Result revealed a non-statistical difference on the mean scores of all the pairs in the pre-test but revealed a statistical difference on the mean scores of all the pairs in the post-test.

Table 8. *Multiple comparison between the concept test mean scores*

Groups	Pre-test			Post-test		
	Group A	Group B	Group C	Group A	Group B	Group C
Group A	…	p > 0.05	p > 0.05	…	p < 0.05	p < 0.05
Group B	…	…	p > 0.05	…	…	p < 0.05
Group C	…	…	…	…	…	…

4. Discussion

The main effects of supportive graphical interventions on the graphing skill of the students were investigated using the graphing skill test. Results showed that the number of students who constructed low-level graphs were higher than the number of students who constructed high-level graphs, both for the pre-test and post-test. Almost all of the participants in the study have constructed low-level graphs before and after the interventions. The high number of students who consistently constructed low-level graphs indicates complex processes needed in dealing with graphs. These cognitive processes include interactions between graphical representations presence in graphs to form meaningful interpretations. Nevertheless, the complex processes needed in dealing with graphs might be the contributing factors why students have experienced difficulties in constructing high-level graphs (Bollen et al., 2017). Results also showed that there was a significant increase in the number of high-level graphs constructed by the students who received instructions in construction and extraction of graphs. The significant increase in the number of high-level graphs constructed by the students who received instructions in construction and extraction of graphs indicates that supportive graphical intervention in construction and extraction of graphs has improved students' comprehension in graphs, and thus improve also their skills in graphing. The results also revealed a main effect of graphical interventions on the graphing skills of the students. This indicates that the inclusion of graphical intervention in physics teaching has significantly contributed to students' graphing skills compared to passive presentations of graphs and independent construction and extraction of graphs. These results were confirmed using Tukey HSD *post-hoc* pairwise comparisons. In a pre-test-post-test study conducted by Harsh and Schmitt-Harsh (2016), they found out that explicit teaching instruction in graphs has improved the graphing skills of undergraduate students in science. Furthermore, in the study conducted by Meisadewi, Anggraeni and Supriatno (2019), they also ascertain that lab activities, which integrate active construction and extraction of graph activities, improved the graphing skills of students in lab science courses. The positive effects of explicit graphical interventions are very important to students, since these skills are very important in studying science and mathematics, as well as in students' everyday life. This could open new opportunities to explore other representations essential to physics teaching other than graphs, and design learning strategies that maximize the use of other representations useful to learning. Moreover, the non-significant differences among the number of high-level graphs constructed before the instructions contributes to the internal validity of this study. The non-significant result increases the probability that the results are due to the graphical interventions and not on the academic experiences and maturations of the students. Conceptual understanding is often associated with effective learning, this is why the effects of supportive graphical intervention were investigated in this study. A significant increase in the mean scores of the students in the concept test has been observed after the instructions, which is the same for all three groups. The significant change indicates a substantial improvement in the conceptual understanding of the students in mechanics after undergoing graphical intervention. In the study conducted by Stefanel (2019), it was articulated that modelling graphical representations activate conceptual understanding. The cognitive processes involve in reading and interpreting graphs, for example, facilitate the development of the conceptual learning, and are also part of the learning development in school. Activating students' graphical comprehension through supportive graphical interventions, promotes students' graphing skills and conceptual learning. ANOVA in the concept test mean scores revealed a significant main effect of graphical interventions in the conceptual understanding of students in mechanics. The significant result implies that instructions in construction and extraction of graphs have greatly improved students' conceptual understanding than those groups who used passive representations and independent construction of graphs. Furthermore, the non-significant result in the pre-test has contributed to the internal validity of this study (Table 7). The non-significant result has lessened the effect of non-random sampling and has lessened the effect of students' maturation and experiences to the result of the study. This indicates a greater probability that the gain in scores of the students in the concept test was due to the graphical interventions.

5. Conclusion

Skills in reading and interpreting graphs are very important in science and mathematics learning, as well as in everyday life. However, there were students whose skills in reading and interpreting graphs are lacking, in common situations. To lessen the negative impact of students' lack of skill and difficulties in dealing with graphs, students must be supported using graphical interventions that will guide them on the proper construction and extraction of graphs. Thus, the use of supportive graphical interventions in teaching guides students in the proper construction and extraction of graphs, which support students' graphical comprehension of activation of conceptual understanding. To understand the importance of supportive graphical interventions on the graphing skill and conceptual understanding of undergraduate students in physics, their graphing skill and conceptual understanding were evaluated before and after they were subjected to graphical interventions: Passive presentation of graphs, active construction and extraction of graphs, and independent construction and extraction of graphs. A significant gain in the number of high-level graphs has been observed for those students who were exposed to instructions in construction and extraction of graphs. Among the three graphical interventions, active construction and extraction of graphs has the highest positive effect on the graphing skill of the students, as most of the students experienced difficulties in constructing and extracting graph due to a consistent high number of low-level graphs constructed by the students. Moreover, it was observed that all supportive graphical interventions explored in this study are effective in activating students' conceptual learning in physics, as all the students significantly gain on their scores after they were exposed to the three interventions. Results revealed that all graphical interventions are effective in improving students' conceptual learning while active construction and extraction of graphs are effective in improving students' graphing skills. Although this study is limited only to quantitative data, as qualitative data might provide more clearer perspectives, students' lack of skills in dealing with graphs could be remedied through the inclusions of teaching interventions. Through this, science learning will become more productive since improving learners' graphing skills signify improving learners' ability to grasp information from graphs.

6. Recommendation

The processes involved in reading and constructing graphs are essential in the development of critical thinking skills and problem-solving skills. During the process of construction of graphs, students undergo the process of identifying variables, symbols and text needed in building graphs. Through this, students will become familiar and aware of the different representations presence in graphs and be able to establish graphical representations in their mind. These mental representations developed during the process of construction of graphs are very helpful when students read and interpret graphs. It suggests that learners should be engaged both in active construction and extraction of graphs, as both activities promote graphical comprehension and higher thinking skills.

Acknowledgement

The author would like to express his sincerest gratitude to all who participated in this research activity.

References

Angra, A., & Gardner, S. M. (2016). Development of a framework for graph choice and construction. *Advance Physiology Education, 40*, 123–128. doi:10.1152/advan.00152.2015

Bollen, L., van Kampen, P., Baily, C., Kelly, M., & De Cock, M. (2017). Student difficulties regarding symbolic and graphical representations of vector fields. *Physical Review Physics Educational Research, 13(2*), 020109. doi:10.1103/PhysRevPhysEducRes.13.020109

Dart, E. H., & Radley, K. C. (2018). Toward a standard assembly of linear graphs. *School Psychology Quarterly, 33(3), 350-355*. doi:10.1037/spq0000269

Duijer, C., Van den Heuvel-Panhuizen, M., Veldhuis, M., & Doorman, M. (2019). Supporting primary school students' reasoning about motion graphs through physical experiences. *ZDM Mathematics Education, 51, 899-913.* doi:10.1007/s11858-019-01072-6

Gates, P. (2018). The importance of diagrams, graphics and other visual representations in STEM teaching. In R. Jorgensen & K. Larkin (Eds.), *STEM Education in the Junior Secondary: The State of Play* (pp.169–196). doi:10.1007/978-981-10-5448-8_9

Glazer, N. (2011). Challenges with graph interpretation: a review of the literature. *Studies in Science Education*, *47(2)*, 183-210. doi:10.1080/03057267.2011.605307

Harsh, J. A., & Schmitt-Harsh, M. (2016). Instructional Strategies to Develop Graphing Skills in the College Science Classroom. *The American Biology Teacher, 78(1), 49-56*. doi:10.1525/abt.2016.78.1.49

Lin, JW., & Chiu, MH. (2017). Evaluating multiple analogical representations from students' perceptions In D. F. Treagust, R. Duit & H. F. Fisher (eds.), *Multiple Representations in Physics* (pp.71-91). Springer. doi: 10.1007/978-3-319-58914-5_1

Meisadewi, N., Anggraeni, S., & Supriatno, B. (2017). Improving students' graphing skills through quantitative-based lab activities. *1st Annual Applied Science and Engineering Conference, 180, 1-5*. doi: 10.1088/1757-899X/180/1/012245

Nixon, R. S., Godfrey, T. J., Mayhew, N. T., & Wiegert, C. C. (2016). Undergraduate student construction and interpretation of graph in physics lab activities. *Physics Review Physics Education Research*, 12,010104. doi:10.1103/PhysRevPhysEducRes.12.010104

Opfermann, M., Schmeck, A., & Fischer, H. E. (2017). Multiple representations in physics and science education – why should we use them? In D. F. Treagust, R. Duit & H. F. Fisher (eds.), *Multiple Representations in Physics* (pp.1-22). Springer. doi: 10.1007/978-3-319-58914-5_1

Phage, I. B., Lemmer, M., & Hitge, M. (2017). Probing factors influencing students' graph comprehension regarding four operations in kinematics graphs. *African Journal of Research in Mathematics, Science and Technology, 21(2), 200-2010*. doi:10.1080/18117295.2017.1333751

Remziye Ergül, N. (2018). "Pre-service science teachers' construction and interpretation of graphs." *Universal Journal of Educational Research, 6(1), 139-144.* doi: 10.13189/ujer.2018.060113.

Schnotz, W., & Bannert, M. (2003). Construction and interference in learning from multiple representations. *Learning and Instruction*, *13(2)*, 141–156. doi:10.1016/S0959-4752(02)00017-8

Slutsky, D. J. (2014). The effective use of graphs. *Journal of Wrist Surgery, 3(2)*, 67–68. doi:10.1055/s-0034-1375704

Stefanel, A. (2019). Graph in Physics Education: From representation to conceptual understanding. In G. Pospiech, M. Michelini & BS. Eylon (eds.), *Mathematics in Physics Education* (pp.195-231). Springer, Cham. doi:10.1007/978-3-030-04627-9_9

Stern, E., Aprea, C., & Ebner, H.G. (2003). Improving cros-content transfer in text processing by means of active graphical representation. *Learning and Instruction*, *13*, 191–203. doi:10.1016/S0959-4752(02)00020-8

Taylor, M. F. (2010). Making biology teaching more ""graphic"". *The American Biology Teacher, 72(9), 568-571*. doi:10.1525/abt.2010.72.9.9