Vector in a graph line, is it important to teach physics?

C Poluakan, A Mondolang and S Mongan
Physics Department, Manado State University

Abstract. It has been widely reported in various research journals about the difficulties of students in studying vectors and their application in physics. For this reason, research has been conducted which aims to identify misconceptions about vectors and application in physics concepts and the use of graph lines in the teaching of physics. Therefore research has been carried out based on the use of representation. The research method uses MOMBI which emphasizes the treatment of class formative assessment models. The study was conducted on 39 pre-service teacher students who had studied Mathematical Physics and Mechanics. By comparing the pre-test and post-test scores, the results of the study are that the decrease in score is incorrect in terms of the concept of drawing tail-tips or head-magnitude vectors from 89.7% to 38.4%, and the decrease in score is not correct in terms of implementation in determining the vector of the center of gravity from 92.3% to 35.8% and then the decrease in score is incorrect in terms of the concept of determining position vector from 97.4% to 45%. In conclusion, the use of graph lines in the teaching of vectors has positively increased students' comprehension abilities related to vector concepts and their application in physics concepts. The recommendations of the research results, namely the importance of teaching materials and university physics reference books, include graph lines in the picture of concepts that use vectors, such as vectors of force, momentum, torque and so on.

1. Introduction
The role of mathematical literacy is very important in the development of physics [1]. An example is the use of geometry including vectors [2,3,4]. Vectors are fundamental concepts that can describe and explain physical phenomena in a structured, systematic and compact manner [5]. Physics concepts that are understood correctly will build logical reasoning physics phenomena that are true. On the contrary, without clearing up student misunderstanding of vector concepts, we cannot expect that students will correctly apply vectors in many basic and advanced physics topics [6]. Understanding the correct vector concept is not only limited to understanding the definition of a vector, but mainly relates to how the vector representation, such as tail, tips or head and the location of the vector in the position of the coordinate system. However, as reported by Petrova, H.G. (2016), and preliminary studies conducted by the author, there are many problems in understanding the correct vector concept, because there are still many problems related to understanding graphic literacy by students [7].

Based on some of the ideas above, research has been done that aims to identify misconceptions about vectors and application in physics concepts and the use of graph lines in the teaching of physics. Therefore, the research conducted is based on the use of representations, especially those relating to
determination of tail, tips (head), unit of scale, position vector and determination of the center of weight in the graph line.

2. Conceptual framework

Vectors as geometrically are drawn like lines. The length of the line determines the magnitude of the vector. The direction of the vector is visualized by an arrow at the tips of the line. The starting point of the line is called the tail of vector. How to teach the correct of vector concepts is a serious problem pedagogically, both through teaching materials and through learning interaction in class. Vectors as imaginary lines stating physical quantities such as displacement, velocity, force, momentum, etc., are physical concepts that require a special concentration of thought. Another problem that becomes an obstacle is the very weak mastery of mathematical concepts regarding the position geometry of Cartesian coordinate points. Figure 1 shows the incorrect answer about placing the coordinate points and connecting as vector lines.

Figure 1. Some of the pre-test questions were answered incorrectly by students. Draw vector lines from point A(2,2) to point B(10,12); and point C(17,11) to point D(5,17)

For a long time, a lack of understanding of the basic concept of vectors which has been widely written in various journals and is still being reported, as written by Petrova HG, (2016), quoting from various sources such as Arons (1983), Beichner (1990), Beichner (1994), Bill (2000), Brasell (1993), McDermott (1987), Wavering (1989), namely the fact that many students in high school, or even university level, lose the ability to understand and interpret graphs in physics isn't that new. This has been investigated in several physics education [7,8,9,10,11,12,13,14]. As mentioned above, a lack of understanding of true physics concepts requires a varied and innovative pedagogical approach. An example is the use of graph paper or graph lines. By using graph lines, students are guided to position the coordinates of the points precisely. With the help of graph line will easily make lines connecting the coordinate points. With the graph line it can easily identify the position of the vector tail. Through the use of graph line a direction arrow can be made at the tips of the vector. By using graph paper or graph line will be able to easily calculate the number of units of scale occupied by vector lines. With graph paper will be able to calculate the resultant vector with the Pythagorean formula. With the unit of scale expressed in unit vectors it is easy to write position vectors, as shown in Figure 2.
With a graph line, then students are required to be more fluency and more flexibility in using vectors as part of geometry. As stated by Laurens Bollen et al (2017) that we distinguish between two skills that are needed to benefit from using multiple representations in physics: representational fluency and representational flexibility. Fluency refers to the ability to construct or interpret certain representations like equations, diagrams, or graphs, but also to what extent someone can switch between different representations on demand. Representational flexibility involves making appropriate representational choices when solving problems [5]. Mathematics is not only a tool in the development of physics, but according to Pospiech, that mathematics is the "language of physics" implies that both areas are deeply inter-connected, such that often no separation between "pure" mathematics and "pure" physics is possible [15].

3. Methods
The study was conducted by one shot pre-test post-test design experiment method, on 39 pre-service teacher students who had studied Mathematical Physics and Mechanics. The study was conducted with a representation approach based on the use of graph lines. The learning process uses The Model of Model-Based Instruction (MOMBI). Models which consist of 5 stages, namely: provocation, activation, presentation, scaffolding, practice. The teaching model was chosen based on the view of Ulrike Hanke (2008) that when individuals are confronted with a new learning subject or task, they have to construct a mental model integrating their already existing knowledge and the new information from the learning environment [16]. Research data obtained through instruments that have been carried out expert validation and content validation. Data collection was obtained by CFA (classroom formative assessment) consisting of pre-test and post-test. The following figure is a sample of the results of the student's post-test answers.
Figure 3. Sample post-test answers

Student work results are then identified, examined and checked for correct and incorrect answers. Identification of incorrect answers is shown in the following table.

| Variable | Indicator  | Pre-test (%) | Post-test (%) |
|----------|------------|--------------|---------------|
| Vector lines from tail to tips | Tail point | 90 | 40 |
| | Tips point | 85,6 | 39 |
| | Arrow symbol | 93,8 | 37,8 |
| | Line vector | 89,4 | 36,8 |
| **Average** | 89,7 | **38,4** |
4. Result and discussion

Based on the data in table 1, not all have answered correctly. However, students who answer incorrectly decrease by more than 50%. This fact shows that understanding the concept of physics well requires high concentration and serious attention. Comparing with research conducted by Fauzi (2017) on "Multi-perspective views of students' difficulties with one-dimensional vector and two-dimensional vector", it was stated that many students were still confused to use the “tip-to-tail” strategy to add vectors graphically, we also found that the students just drawn the vector without considering the magnitude of vector accurately [17]. In contrast to the results of Fauzi's research above, we found that for indicators determining the magnitude of vectors the number of diminished percentages of incorrect answers was higher than for other indicators. Based on table 1, the number of reduced wrong answers is not too large, among others, the indicator determines the tail point, the tips point, the coordinates of the tail, coordinate tips and especially writing the position vector formula. The position vector concept is an important concept in studying advanced physics. Position vectors require not only the basis of geometry but also algebraic knowledge. Peter Simon (2009) in the article “Vectors and Beyond: Geometric Algebra and its Philosophical Significance”, writes about the philosophical significance of geometric algebra, namely over the long course of interaction between philosophy and mathematics, the philosophers have tended to pay much more attention to pure than applied mathematics. From this perspective the squabbles between quaternionists and vectorists or the advantages of geometric algebra over the hotch-potch of theories that have come to be standardly applied in physics and engineering are disputed beneath the philosopher's attention threshold, to be qualified as merely pragmatic choices,
less theoretically exciting than incompleteness, consistency, decidability or large cardinals [3]. Based on the findings of the study, this fact shows mastery of physics concepts not only requires a good foundation of physical philosophy, but also a correct foundation of mathematical philosophy such as the understanding of Euclid's Axioms, Phytagorean Theorem and Cartesian coordinates derived from Euclidean Geometry. Besides the basic concepts of physics, mathematical and philosophical concepts of science, physical education will succeed if it is supported by a strong psychological and pedagogical foundation. Since a long time and until now it is still being written about the difficulties of students in understanding the basics of vector concepts and their applications and physics. As written by Cisse (2014) that our study of the evolution of the teaching of vectors shows that the geometric habitat was not “natural” at the beginning. Ideology on teaching and practical reasons often (if not always) have surpassed scientific motives [4]. As written by Nikos Kanderakis (2016), quoting from various sources said that the difficulties of students in applying mathematics in physics have been well documented in the science education literature. It seems that these difficulties are not much related to mastering incomplete mathematical syntax, but rather focused on the meaning of mathematical symbol expressions. This deep understanding, which is related to the construction of mental conceptual schemes that cover the area of knowledge under study, facilitates the transfer of knowledge gained from one problematic situation to another and from mathematics to physics. Therefore, students with inadequate understanding of mathematics may have difficulty using mathematical concepts and procedures in the context of physics [1]. The struggle of physics educators now is to continue to find new, innovative and creative ways so that the learning and teaching of physics concepts can be understood by students learning about physics.

5. Conclusion
The use of graph line is only one of the treatment approaches chosen from the various treatments that can be made. The results of research showed that the use of graphic lines in the teaching of basic vector concepts has reduced the number of students who answered incorrectly. Although students who participated in the study, have not reached 100% answered correctly, but the use of graph line in learning basic vector concepts has given effective results. The use of graph lines in the teaching of vectors has positively increased students' comprehension abilities related to vector concepts and their application in physics concepts. Vector is an essential concept that must be well understood in the introduction to teaching physics. As said by Hamdani Sirat (2017), having a good understanding of basic vector concepts is helpful for students to grasp the concepts of physics, and these findings indicate that having a good understanding of vectors [18]. Research recommendations are very important in physics teaching materials and university physics reference books, using graph lines in concept drawings that use vectors, such as force vectors, momentum, torque, and so on.

6. References
[1] Kanderakis, N. 2016. The Mathematics of High School Physics: Models, Symbols, Algorithmic Operations and Meaning, Science and Education, 25:837-868, DOI 10.1007/s11191-016-9581-5, Springer Science+Business Media Dordrecht 2016.
[2] Clarage, J. B. 2013. The Phytagorean Roots of Introductory Physics, Science and Education, 22:527-542, DOI 10.1007/s11191-012-9553-6, Springer Science+Business Media Dordrecht 2012.
[3] Simons, P. 2009. Vectors and Beyond: Geometric Algebra and its Philosophical Significance, Dialectica, Vol. 63, No 4, pp. 381-395, DOI 10.1111/j.1746-836. 2009.01214.x, Published by Blackwell Publishing Ltd., 9600 Garsington Road, Oxford, OX4 2 DQ, UK and 350 Main Street, Malden, MA 02148, USA
[4] Cisse, B. A., Dorier, J. L., 2014. The Teaching of Vectors in Mathematics and Physics in France during the 20th Century, *Journal of Innovative Technology and Education*, Vol 1, 2014, No 1, 1-10 HIKARI Ltd, www.m-hikari.com, http://dx.doi.org/10.12988/jite.2014.3111.

[5] Bollen, L., van Kampen, P., Baily, Ch., Kelly., De Cock, M., 2017. Student difficulties regarding symbolic and graphical representations of vector fields, *Physical Review Physics Education Research*, 2469-9896/17/132(2)/020109(2017), Publish by the American Physical Society.

[6] Wutchana, U., Emarat, N., 2011. Students’ Understanding of Graphical Vector Addition in One and Two Dimensions, *Eurasian Journal of Physics and Chemistry Education – EJPCE*, 3(2):102-111,2011, journalhomepage:http://www.eurasianjournals.com/index.php/ejpce, ISSN:1306-3049.

[7] Petrova, H. G., 2016. Developing Students’ Graphic Skills in Physics Education at Secondary School, *IOSR Journal of Research & Method in Education (IOSR-JRME)*, e-ISSN:2320-7388, p-ISSN:2320-737X Volume 6, Issue 5 Ver.I (Sept—Oct.2016), PP 123-126, www.iosrjournal.org.

[8] Arons, A.B. Student patterns of thinking and reasoning, part one. *The Phys. Teacher*, 21, 1983, 576-581

[9] Beichner, R.J. The effect of simultaneous motion presentation and graph generation in a kinematics lab. *Journal of Research in Science Teaching*, 27,1990, 803-815

[10] Beichner, R.J. Testing student interpretation of kinematics graphs. *American Journal of Physics*, 62 (8), 1994, 750-756

[11] Bill, L. (2000). The difficulty of interpreting simple motion graphs. *The Physics Teacher*, 38 (2), 2000, 68-69

[12] Brasell, H.M. &Rowe, B.M. Graphing skills among high school physics students. *School Science and Mathematics*, 93, 1993, 63-69

[13] McDermott, L.C., Rosenquist&M.L., Zee, E.H. Student difficulties in connecting graphs and physics: Examples from kinematics. *American Journal of Physics*, 55 (6), 1987, 503-513

[14] Wawering, M.J. Logical reasoning necessary to make line graphs. *Journal of Research in Science Teaching*, 26, 1989, 373-379

[15] Pospiech, G., Eylon, B., Bagno, E., Lehavi, Y., Geyer, MA., 2015. The role of mathematics for physics teaching and understanding, *Conference paper June 2015*, DOI: 10.1393/ncc/2015-15110-6, https://www.researchgate.net/publication/303373032.

[16] Hanke, Ulrike, 2008. Realizing Model-Based Instruction, *Understanding Models for Learning and Instruction*, ed D Ifenthaler, P.Pirnay-Dummer, J.M. Spector (Springer Science+Business Media,LLC International) chapter 9 p 175

[17] Fauzi, A., Kawuri, K. R., Pratiwi, R., 2017. Multi-perspective views of students’ difficulties with one-dimensional vector and two-dimensional vector, *IOP Conf. Series: Journal of Physics: Conf. Series* 795 (2017) 012054, doi: 10.1088/1742-6596/795/1/01254.

[18] Sirait, J. H., Oktaviyant, E., 2017. Analysis of Pre-Service Physics Teachers’ Understanding of Vectors and Forces, *Journal of Turkish Science Education*, Volume 14, Issue 2, June 2017, pp. 82-95, doi:10.12973/tused.10200a, ISSN: 1304-6020.

**Acknowledgments**

Thank you to the Directorate of Research and Community Service, Ministry of Research Technology and Higher Education who funded this research. Thank you to the Rector of Manado State University (Unima) and Chair of The Institution of Research and Community Service (LPPM) Unima for facilitating this research. Thanks to the Dean of the Faculty of Mathematics and Natural Sciences (FMIPA) Unima who has supported the implementation of this research. Thanks to the colleagues of the research team and students in physics education as participants in this study.