P-ISSN: 1693-1246
E-ISSN: 2355-3812
December 2020

Jurnal Pendidikan Fisika Indonesia 16 (2) (2020) 132-139
DOI: 10.15294/jpfi.v16i2.25395

http://journal.unnes.ac.id/nju/index.php/jpfi

The Effectiveness of Head-To-Tail Method in Solving Challenging Physics Tasks

G. M. Sharifov*

Azerbaijan State Pedagogical University, Azerbaijan

Received: 04 September 2020. Accepted: 11 November 2020. Published: December 2020

Abstract

The article deals with the effectiveness of Head-to-tail method for addition vectors. The empirical investigations were carried out at a specialized school. In the research, the number of respondents was 24. As a part of the experiments, it was conducted questionnaires among them and they were given pre-test and post-test, which consists of 12 questions. Statistical analysis was performed using SPSS software. A paired t-test was carried out on pre-test and post-test to determine the possible difference between them. According to the statistically analysed data, it was established that by using Head-to-tail method, students could understand and solve more complicated test task regarding the motion of an object under the many forces. It was concluded that this method could be the best way of solving the most challenging issues related to one or two-dimensional motion and it makes a significant contribution to the more in-depth adoption of the students' understanding of finding the direction of resultant force for numerous forces vectors.

Key words: head-to-tail method, specialized school, vector addition, force, motion

INTRODUCTION

It is generally accepted that the scientific potential of students studying in specialized is considered high-level. This student proved to have substantially logical, critical and creative thinking. It could be explained by the difficult admission process to these schools. Thus, this process is implemented by passing individual qualifying rounds. Therefore, some disciplines such as chemistry, biology and physics are profoundly taught in a specialized school. The primary purpose of physics teaching in a specialized school is to teach deeply students the main essence of each physical phenomena regarding to the surroundings in real life.

The role of vectors in physics teaching has received increased attention across some disciplines in recent years. It is known that vectors being a particular part of mathematics occupy an essential place in physics teaching.

More recently, literature has emerged that offers consistent findings of the effectiveness and drawbacks of using vector concept. Zavala Genaro et al. (2010) found that the students faced difficulties with vector components, in particular choosing answers with incorrect magnitudes after three introductory physics course. Some students thought that the magnitude of a component is equal to the magnitude of the vector and others have problems identifying the magnitude of the components graphically. In order to eliminate to this problem authors used multiple-choice questions asking for students' reasoning to elaborate on the misconceptions and difficulties of graphical representation of the x- and y-components of a vector. They have analyzed and concluded that by this way the students obtained comprehensively understanding of the magnitude of vectors. Knight (1995) investigated the awareness of vectors by 300 university students and found that only one-third of students had information about the vector magnitude and components. The author assumed this fact to be related to their large misconception about vectors. Not knowing about the vector concept leads the students to not comprehensively understand some of the topics in physics, where vectors are most often used (Flores et al. 2004, Aguirre & Rankin 1989, Flores-García et al. 2008, Shaffer & McDermott 2005). Several authors (Roche 1997,

*Correspondence Address:
AZ1000, Uzeyir Hajibeyli str. 68, Baku, Azerbaijan
E-mail: galib_sharifov@mail.ru

Sheets 1998, Loan & Meltzer 2003) have indicated the importance of learners' knowledge about primary vectors calculations to understand some topics in a physics course entirely.

Regarding to computer modelling of vector addition, Çataloğlu (2006) offered free open source software on vector algebra teaching. Nguyen & Meltzer (2003) identified that not taking into account vector components and misconception between scalar and vector addition is the leading cause of students' difficulties in finding a resultant force. A vector addition formed the central focus of a study by Liu et al. (2016) in which the authors found the misconceptions in understanding about force and acceleration. Wutchana et al. (2014) used rubber to visualize the vector addition process. They noted that by this method they could completely clarify the difference between physics concepts "distance" and "displacement".

A recent paper by Richard Moynihan et al. (2020) established the usefulness of vector addition in electrostatics. It was explored the force superposition in electrostatics by using the method of vector addition based on dividing vector components. They determined that the student's lack of mathematical abilities could prevent him from fully understanding of the superposition principle. They emphasized that the inability of students to apply the vector operations correctly could be an additional obstacle for the development of an understanding of electrostatic phenomena. They noted the importance of students' obtaining comprehensive knowledge of vectors before studying the topic of electrostatics.

Greenspoon & Stanley (2000) suggested a new way to eliminate potential uncertainties between the magnitude of a vector and vector components. The using of vectors and its components leads to a comprehensively learning of topics in mechanics, including one-dimensional rectilinear and rotational motions.

A longitudinal exploration of the students' qualitative understanding of graphical vector addition in one and two dimensions by Wutchana & Emarat (2011) reports that main hardships were observed in the vector addition process. Thus, most students do not understand the Head-to-tail method, which leads them to an incomplete understanding of the intricacies of the dynamics in physics. To overcome this difficulty, the authors offered to pay more attention to some points in vectors teaching: (1) students should have a complete understanding of the magnitude and direction of a vector; (2) maintaining a vector's magnitude and direction on the shifting process; (3) by using the Head-to-tail method in vector addition, students should know the vector position.

This section was provided with a summary of the literature regarding the exploration of vector concept understanding. However, there are no any pedagogical investigations about a vector concept in specialized schools. Furthermore, studies mentioned above highlight the need for a detailed explanation of the vector concept in physics subject. Most previous studies on this topic have only focused on simple physics exercise. Therefore, considering the scientific potential of students in a specialized school, it would be more appropriate to investigate the best method for vector addition in some complicated physics exercises. The research questions in this study focused on the investigation of Head-to-tail method for vector addition in some challenging physics tasks about the motion of an object under numerous various forces.

METHOD

The current investigation involved 24 tenth-grade students from a specialized school. It was conducted questionnaires among them to establish whether they could illustrate the resultant force within the motion of an object under the several angled force acting on it or not. The analysis of the results reveals that the students faced some problems on a vector concept.

Problem 1. The students do not fully understand the difference between the two equalities, as shown in Fig.1. The five of them responded by showing the expression $\vec{A} = \vec{B}$ and $|\vec{A}| = \overrightarrow{|B|}$, however, 16 students answered that both pair vectors are equal to each other.

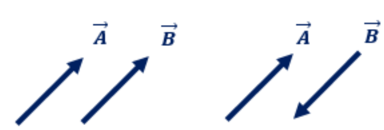

Figure 1. Comparison of vectors

Problem 2. While studying the motion of objects under the forces, students do not know how to increase or decrease acceleration in the same direction. Twenty students said they did not understand it well.

Problem 3. When they are asked about the best way for the vector addition, they answered as follows:

- 12 students - Parallelogram method;
- 8 students – Triangle method;
- 4 students – Component method.

After scrutinizing the results of this questionnaire, it turned out that the leading cause of the problems was their not fully mastering math operations on vectors and not applying them visually. Afterwards, a pedagogical study is carried out to determine the effect of Head-to-tail method, which was considered the best way for vector addition (Wutchana & Emarat, 2011).

At the beginning of the experiments, the students were given the Pre-test (Fig.2) consisting of tests with three levels of difficulty: four easy, four medium, four difficulty. Then, the obtained data were analyzed to determine whether all students could solve test assignments best knowing methods of Parallelogram, Component.

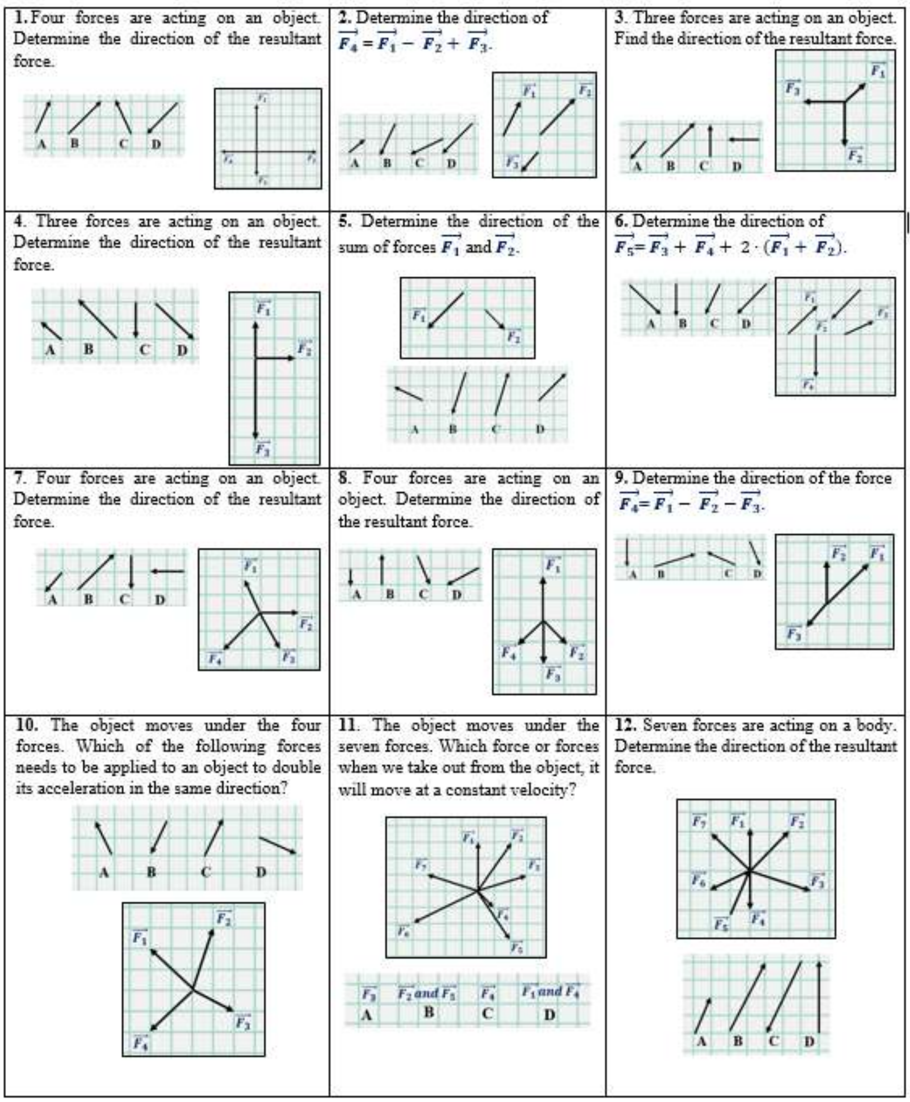

Figure 2. Pre-test

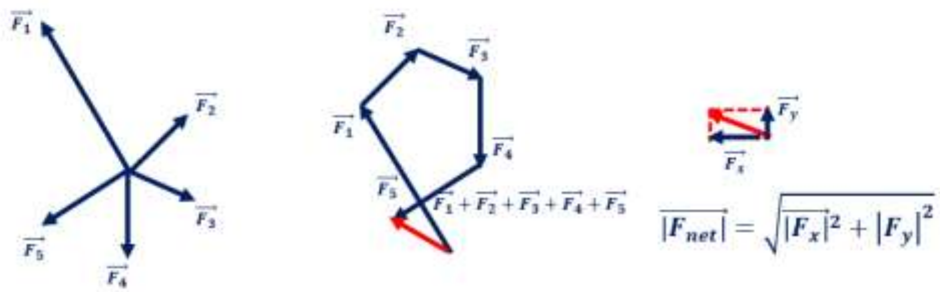

Figure 3. Head-to-tail method for vector addition

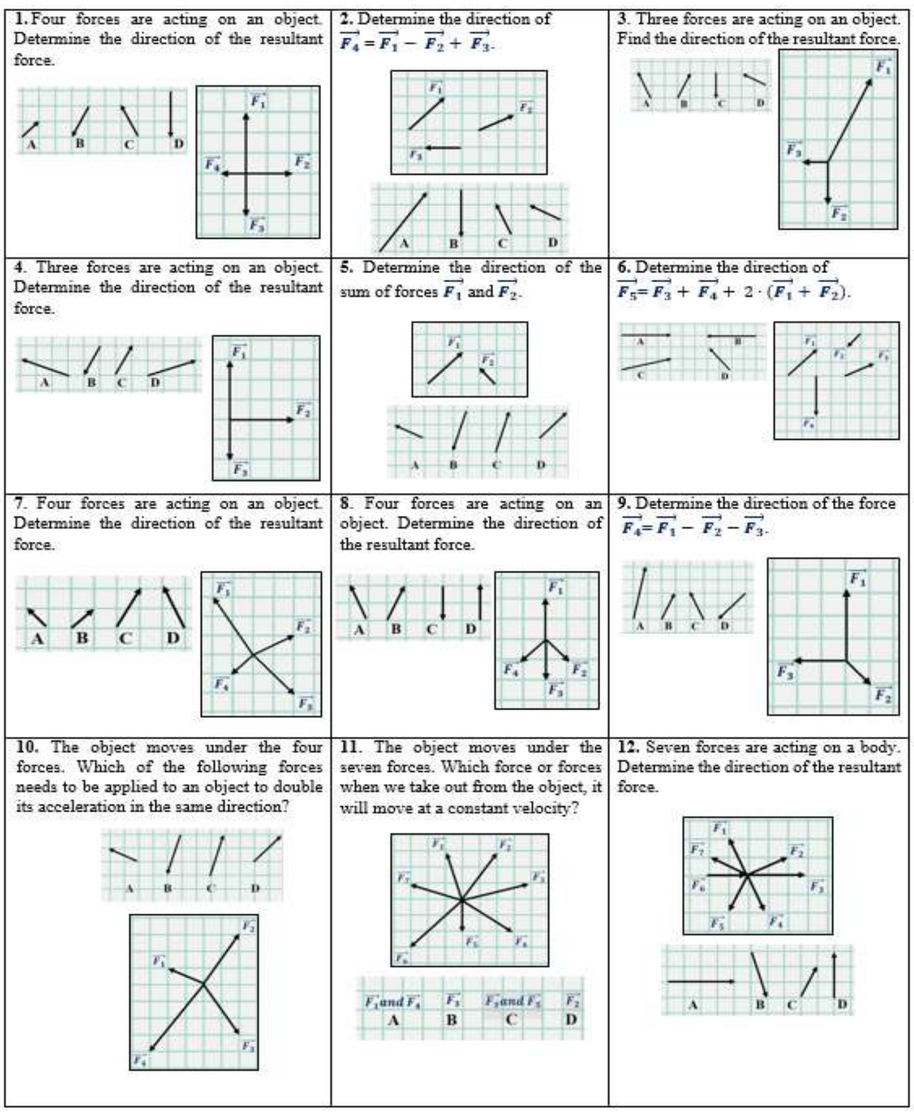

Figure 4. Post-test

Then, the students were taught vector addition based on Head-to-tail method (Fig.3). To determine the difference between Pre- and Post-test, the students were presented the Post-test (Fig.4), which had a similar structure and difficultness as Pre-test.

The results were analyzed through the statistical analysis based on which compared the data was a paired samples t-test. This test enabled me to determine possible significant difference appearing between before and after teaching Head-to-tail method for vector addition. Sometimes, in literature, Triangle method called like a Head-to-tail method; however, the main difference between them is that the Triangle method is for finding a resultant force only for two vectors, but Head-to-tail method is for a large number of vectors.

RESULT AND DISCUSSION

The data obtained in the previous study (Wutchana & Emarat 2011) using graphical vector addition indicated some points to simplify the understanding of vector addition. Zavala Genaro et al. (2010) investigated finding only magnitude of vector, as well as within pedagogical experiments they have used simple tasks. However, in contrast to the above-mentioned researches, in our case, the best-considered method, such as a Head-to-tail method has been experimented and it used challenging tasks within experiments. As a result, it was observed student's ability of solving was improved, i.e. this method enabled the student to comprehend the finding way of the resultant force of many forces. Table 1 shows the results obtained using the SPSS program (Table 1). For all comparisons throughout the survey, a confidence level of 95% ($\alpha = 0.05$) was used. Furthermore, all errors expressed here represent the uncertainty in the means.

The t-test results as shown in Table 1 showed that tenth-grade-students responded correctly a great deal of tests in Post-test (mean= 21.75, SD = 1.6) than in Pre-test (mean = 17.67, SD = 3,4). A repeated-measures t-test found this difference to be significant, $t(11) = 6.57$, $p < .001$.

Table 1. Independent t-test results of control and experimental group students' responses

		Paired Differences							
				Std. Error	95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	Posttest - Pretest	4.08333	2.15146	.62107	2.71636	5.45031	6.575	11	.000

Taking into account that the Sig. (2-Tailed) value in our example is $p < .001$, and I defined that there is a statistically significant difference between the mean scores of answers in Pre- and Post-test. According to Paired Samples Statistics, it was revealed that the mean number of correct answers for the Post-test was higher than that one for the Pre-test. Based on this fact, it could be concluded that while doing the Post-test, participants were able to solve significantly more test assignments than the Pre-test. As can be seen from Fig.5, the median number of correct answers is 16.5 for Pre-test and 22 for Post-test.

Moreover, the size of the interquartile range for Pre-test is the number of 6, i.e. the students which number is in the range 15-21 correctly answered 50% of Pre-test tasks. However, the interquartile range for Post-test is about 3.5, i.e. the students which number is in the range of 20.5 and 23 correctly answered 50% of the post-tests.

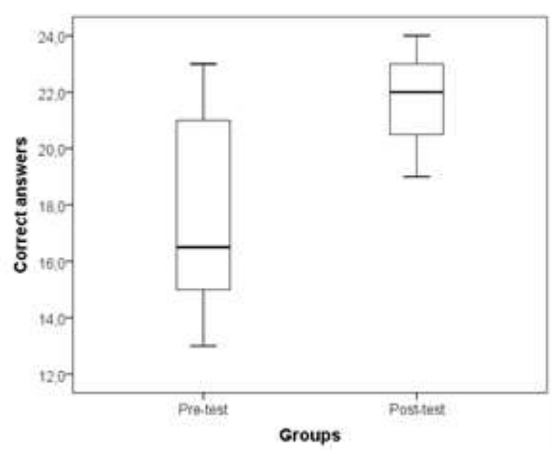

Figure 5. Boxplot for Pre- and Post-test

Boxplot for Pre-test is largely skewed right with a correct answer that has about 13, which may be on minimum. In other words, Fig.5 shows that the median correct answers in Post-test are higher than in Pre-test. Also, the interquartile range, as well as the overall scale of the data set, is significantly higher for the Pre-test.

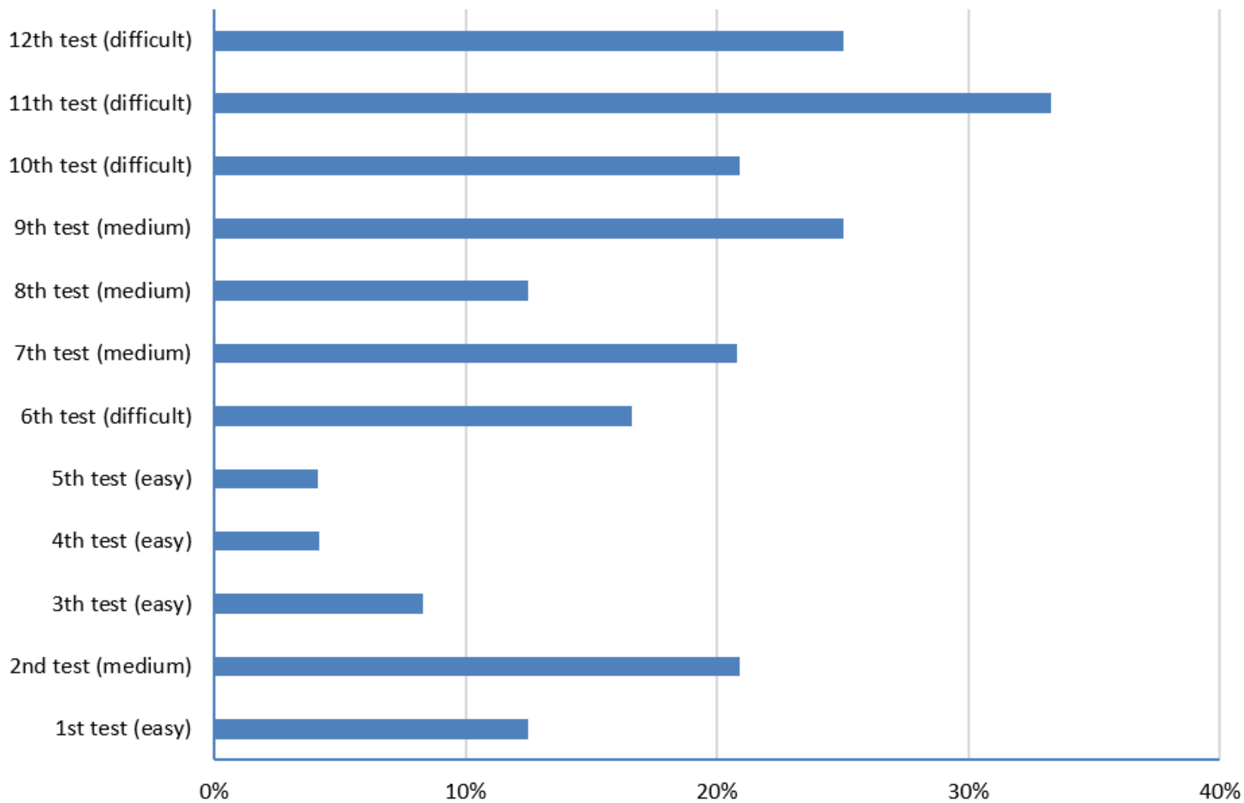

Figure 6. Difference between pre-test and post-test for each test tasks

Fig.6 illustrates the results between pre-test and post-test for each test tasks. As can be seen from Fig.6, the considerable increase has been observed in solving test tasks that were considered as medium and difficult.

Apart from the previous study (Wutchana & Emarat 2011) that was examined Head-to-tail method in solving of simple exercises, the pedagogical experiments in this study have focused on using Head-to-tail method to improve solving of complicated test tasks about an object motion under forces among tenth-grade-students. It is appropriate to note that while learning the motion principle of an object under the influence of several forces in physics in a specialized school, it was usually taken four forces or n number of forces in the vertical and horizontal directions. Within solving this problem, the main attention is paid to the Parallelogram method. The forces lying along the X and Y axes simplifies the solution of the problem. However, the application of the Parallelogram method in solving activities related to specific angled forces causes certain hardships for students. It is generally accepted that finding the resultant force of two forces using the Parallelogram and Component methods, helps to understand only the essence of vector addition. But the result, analyzed in Table 1, and Fig.6 showed that the use of Head-to-tail methods is more effective in solving complex problems regarding the acquisition of forces, rather than the ways of Parallelograms and Component.

The application of Head-to-tail method simplifies solving difficult physics tasks about topics related to vectors in dynamics and enable a student to fully understand as well as improve their logical and critical thinking about a motion under forces. As it can be seen from Post-test, the 12th exercise solution becomes easier by applying the Head-to-tail method on the grid paper. The complexity of this 12th issue is that the force $\overrightarrow{F_6}$ is in the opposite direction apart from the other forces. Therefore, some students mistakenly showed the force of $\overrightarrow{F_6}$ as a resultant force. However, the force of $\overrightarrow{F_6}$ becomes in the same direction as well as in the same magnitude as the net force. So, resultant force becomes twice as large as the vector $\overrightarrow{F_6}$ (Fig.7a).

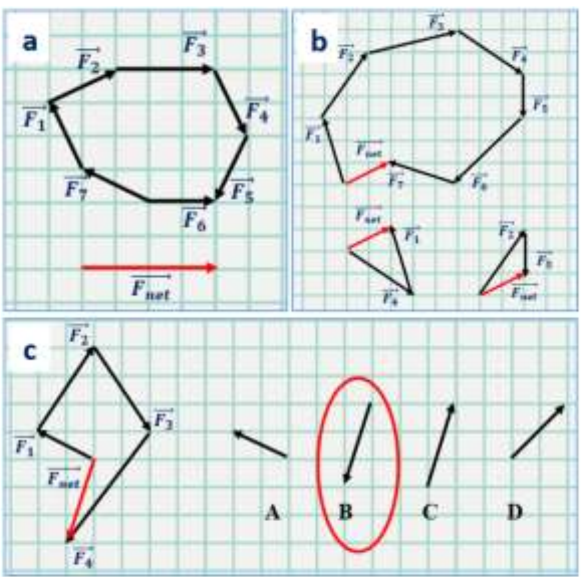

Figure 7. The solution of 12th (a), 11th (b) and 10th (c) exercises in Post-test

The other assignment, the number of which is 11 is related to the complex application of Newton's 1st and 2nd laws. In other words, students must first find the net force and then focus on the removal of a vector in the direction of the net force or two vectors, the sum of which is the net force (Fig.7b). Thus, the answer can be considered one of these pairs: $\overrightarrow{F_1}$ and $\overrightarrow{F_4}$ or $\overrightarrow{F_2}$ and $\overrightarrow{F_5}$. Even though this test was complicated, however, it was highly connected with life. It makes actual the importance for students to be well aware of the main essence of Newton's 1st and 2nd laws along with the mathematical operation on vectors. In order to double the acceleration in the test task No 10, students must firstly find the resultant force. Taking into consideration that the acceleration is directly proportional to the resultant force, then in order to double the acceleration of the object, the magnitude and direction of an additional force should be as the resultant force (Fig.7c). Thus, the answer is considered to be the B section. The choice of C section by some students may be due to *Problem 1* appeared during their questionnaire.

The Parallelogram method in solving the above-discussed difficult physics tasks proved to be complicated and confusing for students. By this method, as it seems from Fig.6, it is possible to solve only easy tasks.

CONCLUSION

In conclusion, the statistical analysis t-test to determine the effectiveness of Head-to-tail method for vector addition showed that this method is very understandable for students to comprehend and to solve more challenging physics task related to vector addition. Besides findings obtained in this study enhance students' understanding of the best way in the teaching process for vector addition. Research in this paper has shown that although students in specialized school may be well-versed in vector mathematics, but the finding of resultant force in one or two-dimensional motion became challenging for them. The best way to overcome these difficulties could be a successful application of the Head-to-tail method, along with the Parallelogram methods.

REFERENCES

Aguirre, J.M. & Rankin, G. (1989). College students' conceptions about vector kinematics. *Phys. Educ,* 24 (5), 290-294

Çataloğlu, E. (2006). Open-source software in teaching physics: A case study on vector algebra and visual representations. *The Turkish Online Journal of Educational Technology*, 5 (1), 68-74

Flores, S., Kanim, S.E. & Kautz, C.H. (2004). Student use of vectors in introductory mechanics. *Am. J. Phys*, 72 (4), 460-468

Flores-García, S., Alfaro-Avena, L.L. & Dena-Ornelas, O. (2008). Students' understanding of vectors in the context of forces. *Revista Mexicana de Física E,* 54 (1), 7-14

Greenspoon, Stanley. (2000). A consistent vector approach to teaching introductory mechanics. *Phys. Educ.* 36. 58-60

Knight, R.D. (1995). The vector knowledge of beginning physics students. *Phys. Teach*, 33(2), 74-77

Liu, Gang & Fang, Ning. (2016). Student Misconceptions about Force and Acceleration in Physics and Engineering Mechanics Education. *Int J Eng Educ.* 32. 19-29

Loan, Ngoc & Meltzer, David. (2003). Initial understanding of vector concepts among students in introductory physics courses. *Am. J. Phys.* 71, 630-638

Nguyen, N. & Meltzer, D. E. (2003). Initial understanding of vector concepts among students in an introductory physics course. *Am. J. Phys*, 71(6), 630-638

Richard Moynihan, Paul van Kampen, Odilla Finlayson and Eilish McLoughlin. (2020). Superposition of vectors and electric fields: a study using structured inquiry tutorial lessons with upper secondary level students. *Phys. Educ*. 55 025012 (10pp)

Roche, J. (1997). Introducing vectors. *Phys. Educ,* 32(5), 339-345

Shaffer, P.S. & McDermott, L.C. (2005). A research-based approach to improving student understanding of the vector nature of kinematical concepts. *Am. J. Phys*, 73(10), 921-931

Sheets, H.D. (1998). Communicating with vectors. *Phys. Teach*, 33(2), 74-77

Wutchana, Umporn & Emarat, N. (2014). Finding resultant vectors using a rubber band. *Phys. Educ.* 49. 141-143

Wutchana, Umporn & Emarat, Narumon. (2011). Students' Understanding of Graphical Vector Addition in One and Two Dimensions. *Eurasian J. Phys. Chem. Educ.*, 3(2), 102-111

Zavala, G., Barniol, P., Singh, C., Sabella, M., Rebello, S. (2010). Students’ Understanding of the Concepts of Vector Components and Vector Products. *AIP Conference Proceedings* 1289, 341-344