Journal of Physics: Conference Series

PAPER • OPEN ACCESS

Underlying variables in the understanding of movement in engineering students

To cite this article: O J Suárez *et al* 2021 *J. Phys.: Conf. Ser.* **2102** 012005

Underlying variables in the understanding of movement in engineering students

O J Suárez[1], A A Gamboa-Suárez[2], and C A Hernández-Suárez[2]
[1] Facultad de Ingeniería, Universidad Autónoma de Colombia, Bogotá, Colombia
[2] Facultad de Educación, Artes y Humanidades, Universidad Francisco de Paula Santander, San José de Cúcuta, Colombia

E-mail: cesaraugusto@ufps.edu.co

Abstract. This article describes the understanding of motion by active students taking Newtonian physics for engineering, supported by active learning, during the pandemic due to COVID-19; in addition, an unsupervised predictive model of learning achievement was constructed from variables identified using the principal component analysis technique on the responses. the instrument used is the modified test of understanding graphs-kinematics comprehension. students from two universities in Bogotá, Colombia participated. The results show a lower level of accuracy in students in remote face-to-face mode, compared to the reference group of physical presence; by way of reflection, the forced educational experiment implies resizing the teaching activity in the teaching and learning of movement.

1. Introduction

In the framework of science education, the need to develop the ability to work with graphs [1-3] has been identified for several decades as one of the representations of mathematical objects necessary [4] for learning kinematics based on algebra or calculus; the teaching and learning of physics, in various forms, are configured as a persistent obstacle in the learning of physics [5], causing situations in which they fail to differentiate velocity with acceleration, position with distance, among others [6]. Active learning, as a strategy that contributes positively to conceptual formation [7,8], has been consolidating as a promising alternative that favors better learning, linking simulations, given that gains have been identified at different educational levels [9-13].

Classical mechanics or Newtonian mechanics corresponds to the first course of general physics, in which the particle model is assumed, in engineering degrees, because it studies the fundamental principles and models that allow understanding mechanical systems, additionally "...they retain their importance in the theories of other areas of physics and serve to describe many natural phenomena..." [14]. Kinematics, as a part of mechanics, focuses on studying motion through position, velocity, acceleration, and time [15]; after some years of research, Sokoloff, and Thornton [7] establish as part of the active learning environment, a set of introductory readings for each topic in the different courses.

This article focuses on the understanding of movement by engineering students, the question that directs this work is What are the underlying factors that predict the achievement of learning achievement of students studying motion in an initial engineering physics course?

2. Method

The approach of this work is mainly quantitative [16]; statistical tests are used to determine the relevance and validity of the instrument; the results of the baseline test used in a face-to-face Spanish-speaking community are compared with the results obtained in remote modality educational conditions, due to the COVID-19 pandemic. The principal component analysis (PCA) technique is applied to determine the underlying variables [17,18]; with the variables found, an unsupervised model is constructed, with the linear regression model; those who participated as students were selected by convenience; they are students who are taking their first course in engineering physics. The ages of the participants are between 17 and 23 years old; fifty-six students participated, of which 10 are in public universities and 46 in private universities; the mode of study is remote face-to-face, the classes are held via a streaming platform (Google Meet®), which is complemented by activities in a virtual classroom.

The test of understanding graphs-kinematics (TUG-K) test was applied online according to the protocol established by the institutions; to establish the level of movement understanding, we used the TUG-K, initially proposed by Beichner [19] with 21 items, which was later updated to 26 questions [3] and translated into Spanish [2]. The Instrument has seven objectives and three concepts as fundamental elements of measurement; the concepts refer to area under the curve and the calculation and interpretation of the slope, the objectives are oriented to determine the speed, acceleration, or displacement [3]. The instrument has been consolidated over time because it has been used in different research projects, some aimed at understanding students' conceptual difficulties [20], defining teaching strategies [21] and even incorporating technology in teaching [13,22].

In both universities, the physics courses are based on active learning, complemented by a set of activities whose origin has been made in the theory of learning styles. The teaching sequence consists of two cycles as shown in Figure 1, one cycle for the study of uniform motion and the other for uniformly accelerated motion. The first part is done with the learning steps supported by videos made with mobile devices and processed with the Video Tracker® software for the demonstrations. In the next part, the topic is developed in lecture form, hypothetical exercise workshops are incorporated [14,15] and some laboratory activities limited by the confinement due to the pandemic are proposed.

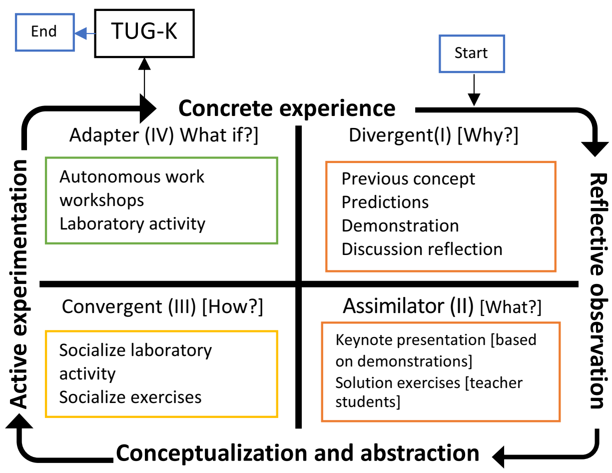

Figure 1. Outline of the didactic sequence.

3. Results and discussion

In the first instance, the statistical tests of the test that has been modified by [3] are verified; the statistical tests are checked and compared in two ways: the item-centered and the global tests of the instrument [23]. The difficulty index and the discrimination index for the items and the Kuder-Richardson index and the Ferguson delta for the overall instrument.

Table 1 contains the values obtained and compared for each of the statistical tests for the TGU-K; for the case under study, the statistical tests fall within the desired range [24], which makes the TUG-K valid in the population under study, although less in value, with respect to the reference group. Therefore, it is possible to affirm that the TUG-K is reliable and meets the appropriate discrimination conditions to be used.

Table 1. Summary of statistical tests performed for the modified TUG-K test (reference) with the study population (the case).

Statistical test	Desired values	Reference	The case study
Difficulty index	(0.30 - 0.90)	Average: 0.60	Average: 0.31
Discrimination index	≥ 0.30	Average: 0.59	Average: 0.43
Biserial point coefficient	≥ 0.20	Average: 0.49	Average: 0.36
Kuder-Richardson index	≥ 0.70 for group stockings	0.87	0.82
Ferguson delta	> 0.90	0.99	0.96

The learning achievement of the students is assumed from the correct answers to each of the questions. A value of 1 is assigned for a hit and 0 for a miss. All the correct answers are added up (Hits) and the percentage value (P) of the correct answer is calculated as in Equation (1).

$$P = \frac{(\text{Hits})}{26} \text{x } 100\%. \quad (1)$$

The score of the students in the study group was 31% compared to 60% in the reference group [2]; when comparing between the study group with the reference group [3], each of the objectives tending to determine the velocity, acceleration or position using the concepts dependent and area under the curve, the study group obtains a score below the reference group, noting a greater difference when the slope calculation is required. It cannot be established with total certainty that the clearly different results correspond to the study modality in pandemic, but it is certain that, apparently, there is a negative impact on the score.

On the other hand, the reference course is based on calculus as opposed to the study group, which is based on algebra, which did not show significant differences; to get closer to understanding what underlies the study of movement, the PCA technique is applied to find the variables that underlie the students under stud; the assumptions Kaiser-Meyer-Olkin measure = 0.709, the sphericity test ($\chi^2 = 248.544$, gl = 105, significant = 0.000). Verified the assumptions, applied the technique converged in 5 iterations.

The components emerging from the study are four, namely (1) acceleration (P8, P9, P7, P11; $\sigma^2 = 17.1\%$); (2) calculations and inferences from graphs (O10, P19, P6, P2; $\sigma^2 = 15.2\%$); (3) inferences from graphs (P25, P17, P26; $\sigma^2 = 14.3\%$); (4) velocity (P5, P13, P15, P1; $\sigma^2 = 14.1\%$). The total variance explained by the four underlying variables is 60.47%.

The acceleration component (a) emerges as a variable in which the change in velocity in the unit of time has implications for the different ways in which it can be represented and interpreted; the component calculations and inferences from graphs (Cal). This underlying variable involves the student performing some arithmetical calculations from the graphs, as well as a level of abstraction and generalization of the arithmetical behaviors of the changes, from observing the graphical representation of the movement.

The inferences from the graphs component (IG), in this variable converges the cognitive exercise on the part of the student of observing the graph and making a process of abstraction and interpretation, located in the variable under study, be it position, velocity or acceleration; the component velocity (v), this underlying variable, is strongly related to the study of velocity in its different representations, as well as its interaction with the notion of acceleration.

This means that understanding velocity from its different representations, closely localized in concrete situations and at the same time achieving the necessary level of abstraction, contributes to the understanding of movement in one dimension; since the four underlying variables are the result of applying the PCA technique, they comply with the assumptions of independence, normality, non-collinearity, and normality. In addition, the homoscedasticity of the variables is verified; the linear regression model by introduction is used, identifying compliance with the assumptions are shown in Table 2.

Table 2. Summary of model predictive of learning achievement.

Model	R	R-square	Adjusted R-square	S ϵ e[b]	Statistics of change					Durbin-Watson
					C R-square[c]	C F[d]	gl1	gl2	S F[e]	
1	0.941[a]	0.886	0.877	1.78232	0.886	99.012	4	51	0.000	2.010

[a] Predictors: velocity (v); inferences from graphs (IG); calculations and inferences from graphs (Cal); acceleration (a).
[b] S ϵ e: standard error of the estimate
[c] C R-square: change in R-square
[d] C F: change in F
[e] S F: Significant F change

The unsupervised model predicting the total points earned by students has a prediction of 88.6%, with an adjusted R-squared of 87.7%, of the students who participated. Although the model, Table 3, has limitations, it provides initial empirical evidence for the teaching-learning of movement in one dimension.

The underlying variables allow us to identify some elements to consider in the preparation of activities for the absence of physics that related to the teaching of movement in one dimension; this implies going deeper into the analysis of acceleration in its different representations and its connection with the analysis of the phenomena of movement.

On the other hand, considering numerical calculation as a necessary activity that is directly related to the type of physics course based on algebra, given that students are cognitively constructing the notion of variable. Finally, to deepen the transposition of the various representations of the mathematical objects involved in motion in one-dimension, linear function, and quadratic function.

Table 3. Regression coefficients of the dependent variable "TotalPoints".

Coefficients[a]									
Model	Unstandardized coefficients		Standardized coefficients	t	S[c]	95.0% confidence interval for B		Collinearity statistics	
	B	D ϵ[b]	Beta			Lower limit	Upper limit	T[d]	VIF
Constant	8.125	0.238		34.114	0.000	7.647	8.603		
a	2.676	0.240	0.527	11.136	0.000	2.194	3.159	1.000	1.000
Cal	2.515	0.240	0.495	10.466	0.000	2.033	2.998	1.000	1.000
IG	2.171	0.240	0.427	9.034	0.000	1.689	2.654	1.000	1.000
v	2.162	0.240	0.425	8.994	0.000	1.679	2.644	1.000	1.000

[a] Dependent variable: TotalPoints; TotalPoints = 8.125+2.676 (a) + 2,515 (Cal) + 2.171 (IG) + 2.162 (v)
[b] D ϵ: Deviation Error
[c] S: Significant
[d] T: Tolerance

4. Conclusions

The four underlying variables identified have implications for the exercise of teaching physics, which involve identifying the need to create activities that contribute to this cognitive exercise, to move from concrete situations to abstract thinking. In this sense, it is necessary to strengthen the different representations, as well as their transitions, of the mathematical object linear function and quadratic function. It seems that the forced educational experiment of home study through remote attendance, due to the COVID-19 pandemic, has had a negative impact on the learning achievement of students studying engineering physics. Further research is needed to help identify the factors involved and their future implications.

In addition, it is necessary to advance in the incorporation of emerging technologies in the teaching of physics, since these allow the construction of some representations in a visible way, facilitating the cognitive processes related to abstraction. Finally, some limitations of the present research should be noted: participants located in a metropolis with stable internet connectivity, participation via remote access. However, the TUG-K instrument performed adequately from a statistical point of view, so the results obtained are empirical evidence of the reality of students in remote mode.

References

[1] Beichner R 1664 *American Journal Physics* **62(8)** 750
[2] Zavala G, Barniol P, Tejeda S 2019 *Revista Mexicana Física E* **65(2)** 162
[3] Zavala G, Tejeda S, Barniol P, Beichner R 2017 *Physical Review Physics Education Research* **13(2)** 020111:1
[4] Suárez O 2016 *Revista Academia y Virtualidad* **9(1)** 24
[5] Bastién G M, Mora C, Sánchez D 2010 *Latin American Journal Physics Education* **4(3)** 677
[6] Van-Den-Eynde S, Van-Kampen P, Van-Dooren W, De-Cock M 2019 *Physical Review Physics Education Research* **15(2)** 20113:1
[7] Sokoloff D R, Thornton R K 1997 *The Physics Teacher* **35** 340
[8] Thornton R K, Sokoloff D R 1998 *American Journal of Physics* **66(4)** 338
[9] Osses S, Jaramillo S 2008 *Estudios pedagógicos* **34(1)** 187
[10] Moreno J A, Martínez N Y 2017 *Amazônia: Revista de Educação em Ciências e Matemáticas* **13(26)** 80
[11] Martínez N Y, Riveros S Y 2019 *Tecné Episteme y Didaxis* **45** 35
[12] Rachniyom S, Sujarittham T, Wuttiprom S 2019 *Journal of Physics: Conference Series* **1380(1)** 012105:1
[13] Antwi V, Savelsbergh E, Eijkelhof H 2018 *Journal of Physics: Conference Series* **1076**(1) 012002:1
[14] Serway R, Jewett J 2008 *Física para Ciencias e Ingeniería* vol 1 (Cruz Manca: Cengage Learning Editores)
[15] Young H, Freedman R 2009 *Física Universitaria* vol 1 (Naucalpan de Juárez: Pearson Educación)
[16] Hernández-Sampieri R, Fernández-Collado C, Baptista-Lucio M 2014 *Metodología de la Investigación* (Ciudad de México: McGraw Hill Intereamericana)
[17] Walpole R, Myers R, Myers S 2007 *Probabilidad y Estadística para Ingeniería y Ciencias* (Naucalpan de Juárez: Editorial Pearson Educación)
[18] Polo-Miranda C 2009 *Estadística Multivariable* (Madrid: Ediciones UPC)
[19] Beichner R 1994 *American Association of Physics Teachers* **62(8)** 750
[20] Kadri-Ayop S, Tarmimi-Ismail A 2019 *International Journal of Academic Research in Business and Social Sciences* **9(2)** 1278
[21] Dale Z, DeStefano P, Shaaban L, Siebert C, Widenhorn R 2020 *American Journal of Physics* **88(10)** 825
[22] Beichner R J 1996 *American Journal of Physics* **64(10)** 1272
[23] Ding L, Chabay R, Sherwood B, Beichner R 2006 *Physical Review Special Topics - Physics Education Research* **2(1)** 010105:1