Hands-on Physics Bibliography

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Abstract. *Hands-on Physics Experiments (HPhysE) are well-known educational resources, as it is assumed that touching and manipulating material and objects could lead to a deeper understanding than that obtained from vision or sound alone. This work presents an assessment of partial published literature from 1980 onwards treating HPhysE and some general remarks.*

Keywords: Bibliography, Physics, Statistical Analysis.

1. Introduction.

Physics, as a basic and fundamental science, is a predominant part of the general educational curricula. It is likewise a reference for understanding many parts of current science and technology as well as the many social phenomena affected by both science and technology. However, this potential importance is not recognised socially and therefore confers a simple and poor image of this science. Amongst the many activities that can be used for making knowledge of Physics and its learning, more attractive is that of Hands-on Physics Experiments (HPhysE) where an understanding of natural processes is carried out via direct observations and experience [1,2,3]. Usually, HPhysE can be found at "interactive" science and technology centres, but an important effort has been made in order to import them into schools [4,5]

One of the difficulties in bringing the world of science and technology closer is that the methodology used for presenting their concepts, principles and laws is inadequate. Apparently, the use of the so called "scientific method" at the very minimum would mean a predisposition to science and research. On the other hand, the real participation in a task and therefore achievement, are determined to a greater extent by the amount of interest that the task can generate. Therefore, rather than stick to a mere introduction of established knowledge, a real possibility to approach and experience scientific tasks and the use of "scientific methods" in an applied manner is envisaged [6,7]. In this case, it appears that conceptual comprehension is best stimulated by way of participation in "scientific research" and by providing enough opportunities and support for reflection. All of the above leads to a closer understanding of the nature of science and technology [8].

Figure 1. Hands-on Physics Experiments.

The growing interest in design, development and evaluation of these types of HPhysE can be appreciated by the increasing number of publications on such topics in journals related to Teaching Physics [9,10]. This type of information can be seen in American journals such as "The Physics Teacher" [11] (which covers a wide educational spectrum) and the "American Journal of Physics" [12] (centred more on the university area), not forgetting the European journals such as "Physics Education" [13] and "European Journal of Physics" [14]. At first sight, the field continues to expand as newer HPhysE come into being when a) new applications are established, b) there is a redesign due to imitation, change or transformation, c) modifications are made, or d) contents are changed. Many a time, some HPhysE have been replaced by new HPhysE. Although many such HPhysE can be found in books [15,16,17,18] or even on web pages [19,20,21,22], they however do not have a systematic distribution and therefore there arises the need for a study of their present state and evolution over time.

This work is a first attempt to study the present state of literature published in journals from 1980 onwards. Each identified article was classified according to the different categories, which enabled the establishment of a time analysis, a relative weighting and/or the identification of relevant topics. Likewise, the data were subject to an association or contingency analyses with a view to obtaining a cause-effect relationship between the different categories.

2. Classification and description.

A detailed search was carried out for articles in journals such as “The Physics Teacher” (PT) and “Physics Education” (PE).

About 700 articles (70.1% in PT and 29.9% in PE) were identified and classified into the following types:

a) topic: Electromagnetism (10.5%), Fluids (8.2%), Kinematics (4.9%), Vibrations and Waves (19.0%), Static Electricity (5.2%), Modern Physics (4.9%), Optics (12.9%), Other (1.0%), Multitopic (4.6%), Magnetism (4.6%), Dynamic and Static (21.1%) and Thermodynamics (3.1%).

b) author institution: university (56.2%), college (14.5%), high school (12.7%), school (5.4%), and others (11.3%) (museums, individuals, laboratories, companies,…);

c) author country; d) number of pages and e) use of overhead projector.

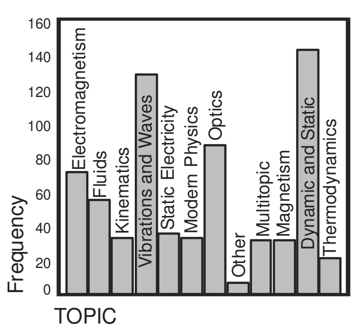


Figure 2. Distribution by topic.

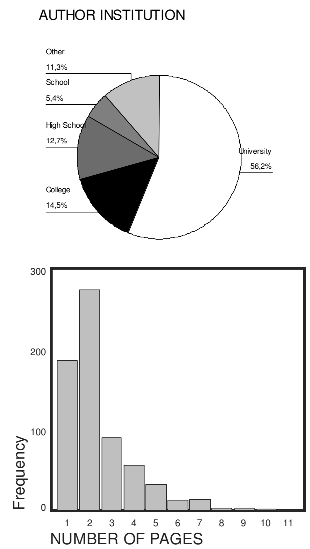


Figure 3. Distribution by author institution (top) and number of pages (bottom).

A relative characteristics analysis related to the nature of HPhysE was likewise undertaken for each article, where each was subject to cost, preparation time, theoretical and practical level (on a scale from very low, low, medium and high). The results of such a classification can be seen on the obtained graphs.

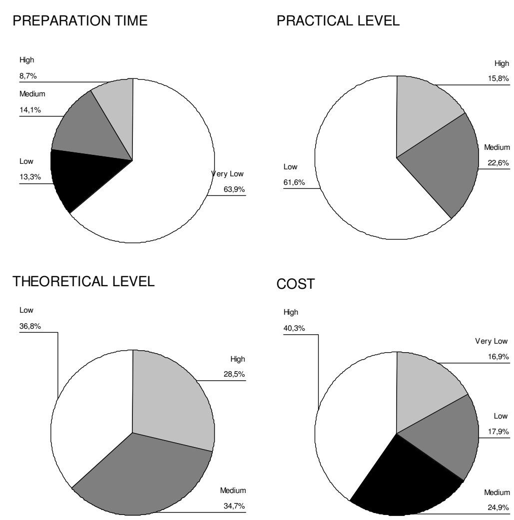


Figure 4. Percentages for preparation time, practical level, theoretical level and cost for the analyzed HPhysE.

From an analytical point of view, since these are qualitative variables, we can highlight on the mode results and on the extreme values. Thus we can emphasize that: a) 95.6% of the articles deal with just one exclusive topic, b) most of the authors are from the USA (60.6%) and the UK (17.1%), c) the institution which publishes most is the university (56.2%), d) the number of pages is either one (27.6%) or two pages (40.6%), e) although the level of preparation needed is usually low (63,9%) there is a sizeable percentage of high cost HPhysE (40.3%), f) just 12.6% use, or can easily adapt, a overhead projector for a greater public viewing, g) although the theoretical level is pretty similar, the practical level is quite low, h) only 6.1% of the HPhysE are models, and finally i) just 6.2% of the HPhysE use toys.

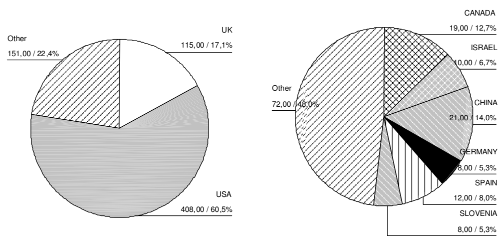


Figure 5. Distribution by author country.

It is also worth noting that within each topic, there are certain themes that repeat more frequently: Kinematics/Circular Movement (14.7%), Dynamic & Static/Centre of Mass (15.5%), Oscillations & Waves/ Interference (16.2%), Fluids/Cartesian Diver (16.7%), Static Electricity/ Electroscope (14.3%), Magnetism/ Field (38.7%), Electromagnetism/Induction (37.1%), Optics/Refraction (29.9%), Thermodynamics/Ideal Gases (14.3%) or Modern Physics/Chaos (14.28%).

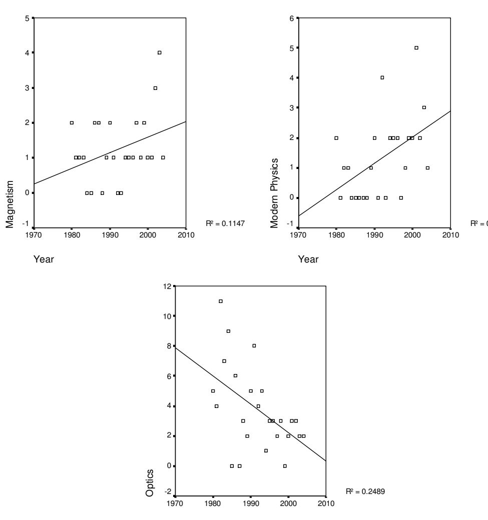


Figure 6. Temporal evolution from 1980 onwards for selected topics.

Finally, a time evolution analysis shows an increasing trend towards topics such as Magnetism and Modern Physics and a decreasing trend towards topics such as Optics.

3. Statistical Analysis.

A contingency analysis was carried out using SPSS11.5 for Windows [23] with a view to analysing the causality relationship between the different categories of the qualitative variables. This analysis is used to study the possible relationship, association or dependence between a pair of qualitative variables and the strength or intensity of such an association. We are talking about developing a hypothesis where a null hypothesis means the existence of independence as against the existence of association or dependence. The differences between the characteristics of the null hypothesis and that of the two variables observed are studied using a statistical Chi-Square test (χ^2 with (r-1)×(s-1) degree of freedom (where r and s respectively represent the rows and columns of the contingency table). If the p-value is less than 0.05, the null hypothesis is refused with a 95% confidence limit, which will mean the acceptance of the alternative hypothesis and therefore the existence of association or dependence. Cramer's V coefficient is usually used to get an idea of the intensity of such an association, which depends on χ^2 but which reduces its value to an interval between 0 and 1, such that the nearer the value to 1, the more intense is the relationship and the nearer the value to 0, the least is the relationship.

The most significant associations are shown in the graphs and the main results are shown in summary table (Appendix 1) where one can see the value of statistical contrast χ^2, the corresponding degrees of freedom, Cramer's V coefficient and the significance of the association (a p-value <0.05 indicates the existence of a significant relationship with a 95% confidence limit).

Therefore, we can highlight that there does not exist (see Appendix 1) any significant relationship between the pairs of variables:

a) cost/journal,
b) institution/cost,
c) institution/number of pages,
d) institution/preparation time or
e) institution/theoretical level

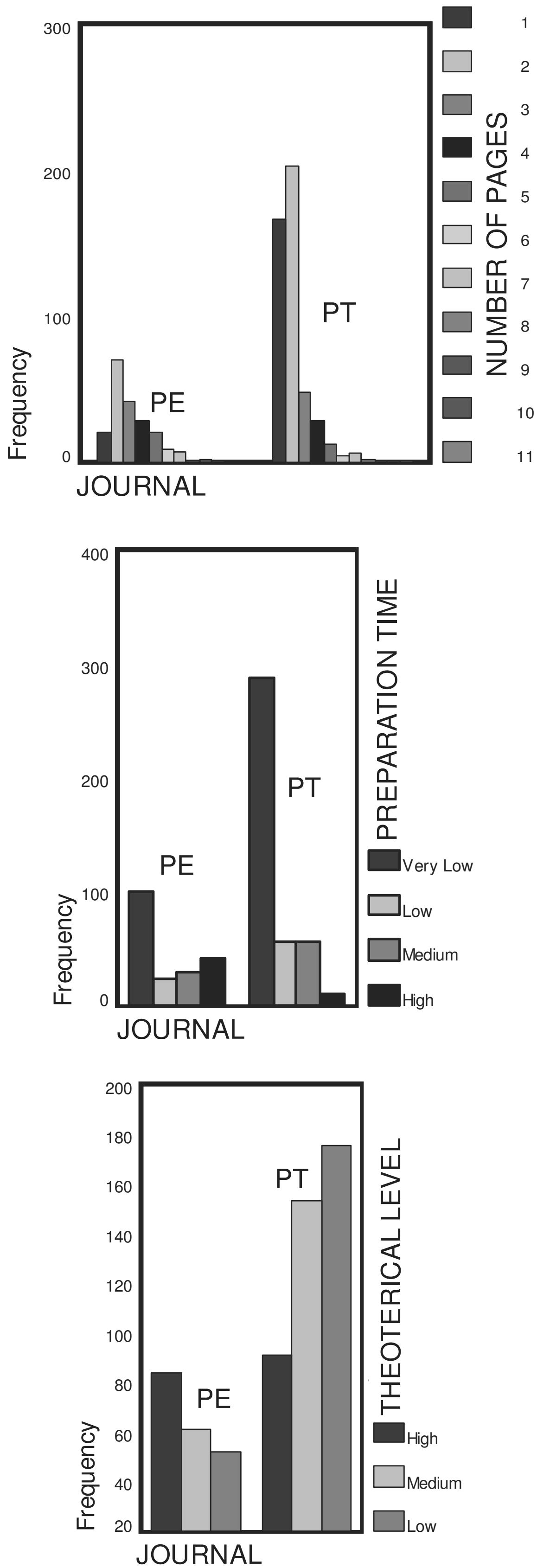


Figure 7. Significant association (from top to bottom) between the pairs of variables journal/number of pages, journal/preparation time and journal/theoretical level.

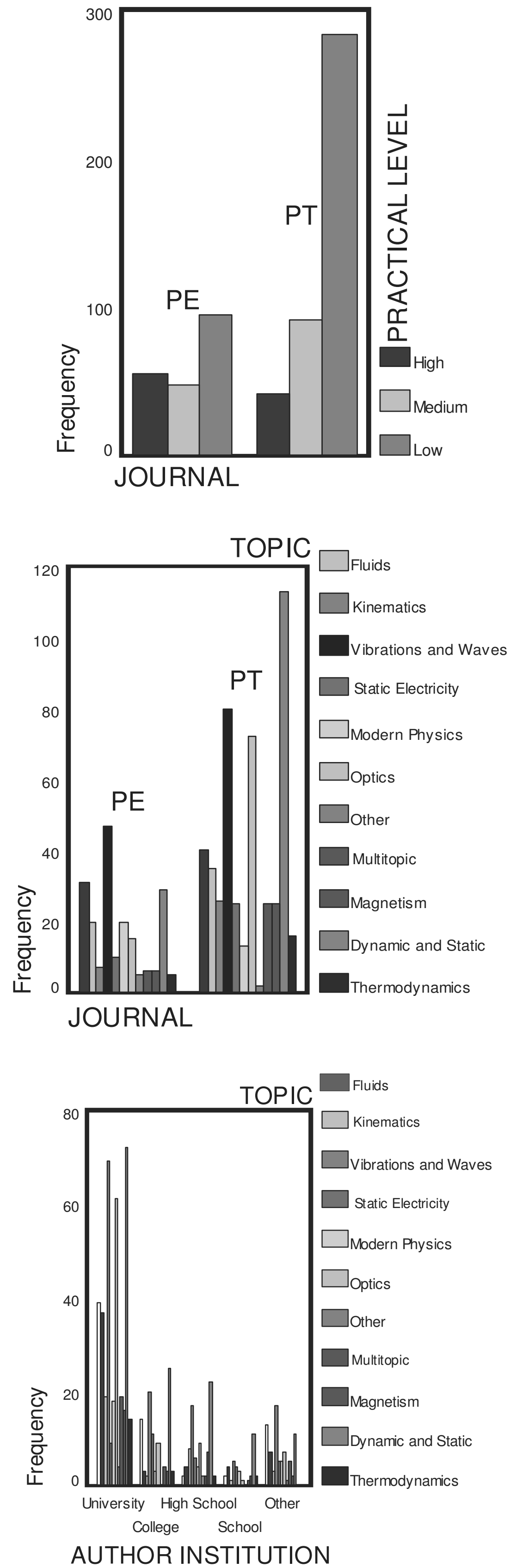
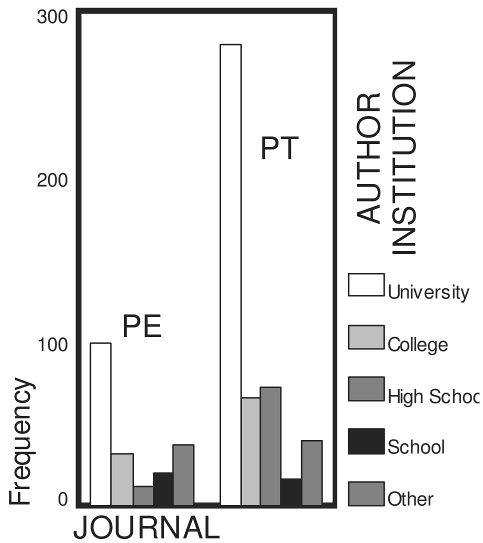
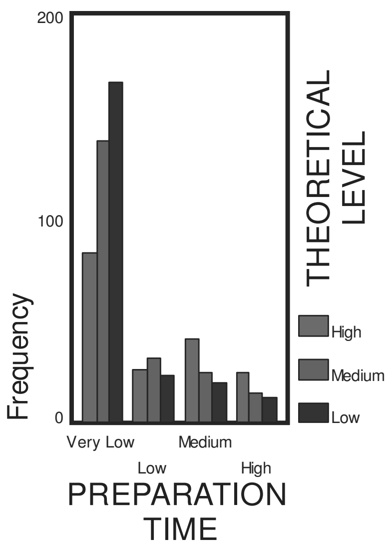


Figure 8. Same as Fig.7 but for the pairs of variables journal/practical level, journal/topic and author institution/topic.





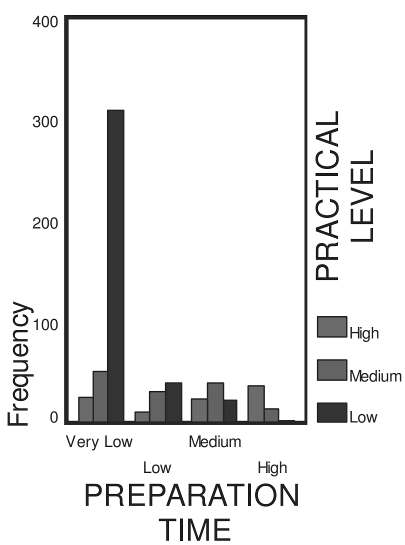


Figure 9. Same as Fig.7 but for the pairs of variables journal/author institution, preparation time/ theoretical level and preparation time/practical level.

At the same time, there exists a weak significant relationship between the pairs of variables journal/number of pages (PE publishes bigger articles), journal/preparation time (PT offers HPhysE with the least time), journal/theoretical level (PT<PE), journal /practical level (PT<PE), journal/topic (PT publishes more of Optics/Dynamic & Static, while PE tends to publish more of Electromagnetism/Vibrations and Waves /Modern Physics), country/institution (the American authors are normally from University/College, while those from UK are mostly from College/High School), institution/category (according to the institution, the weighting for the topics is different), theoretical level/time (greater the theoretical complexity, the greater is the preparation time), and lastly practical level/time (HPhysE that need a higher preparation time are the most complex).

Figure 10. Hands-on Physics Experiments.

4. Conclusions.

A detailed analysis of the articles published in PT and PE from 1980 onwards has enabled the identification and classification of Hands-on Physics Experiments (HphysE). The categories in which the articles are classified clearly show the trend for each topic. Such behavioural trends could be further analysed with data provided by other popular journals related with the subject as “American Journal of Physics” and “European Journal of Physics”. A statistical contingency analysis of the data has enabled the identification of important relationships and deficiencies. There seems to be an observed tradition for design HPhysE in countries such as the USA/UK and a weak incidence in the remaining countries. Such an incidence is also very weak at educational levels such as in High Schools /Schools where the priority ought to be higher. Equally noteworthy is the low percentage of

HPhysE that use an overhead projector and there should perhaps be a greater effort to adapt/create HPhysE so that these can be used more often in the classroom as a demonstration tool.

5. Acknowledgements.

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Appendix 1

	Journal				Institution			
	χ^2	*d.f.*	*V Cr*	*p-val.*	χ^2	*d.f.*	*V Cr*	*p-val.*
Institution	37,185	4	0,236	0,000				
Country	420,995	31	0,792	0,000	218,62	124	0,285	0,000
N-pages	90,136	10	0,366	0,000	48,284	40	0,134	0,000
Cost	1,513	3	0,05	0,679	11,987	12	0,081	0,447
Preparation time	65,003	3	0,327	0,000	14,276	14	0,088	0,283
Theoretical level	30,424	2	0,222	0,000	6,331	8	0,072	0,610
Practical level	36,172	2	0,243	0,000	12,099	8	0,099	0,147
Topic	48,824	11	0,269	0,000	67,840	44	0,159	0,012
	Theoretical level				**Practical level**			
Preparation time	χ^2	*d.f.*	*V Cr*	*p-val*	χ^2	*d.f.*	*V Cr*	*p-val.*
	38,349	6	0,178	0,000	241,374	6	0,446	0,000

Table 1. Summary of contingency analysis. Statistical Chi-Square test coefficient χ^2, the corresponding degrees of freedom , Cramer's V coefficient and the p-value.