Smartphone in school physics: a case study for the experimental obtaining of the acceleration of gravity in the analysis of a spring through a didactic approach

Jhon Alfredo Silva Alé[1]

[1] Departamento de Educación, Universidad de Chile, Santiago, Chile.

jhon.silva@usach.cl

Abstract. In order to meet the demands of curricular updates, this article proposes an advance towards the design of curricular integration guidelines for mobile learning in school mechanics. It emphasizes those objectives associated with the processes and scientific research skills of second year of secondary education (students between 14 and 15 years old), according to the Chilean school organization. For the development of the guidelines, various didactic case studies have been provided that facilitate mobile curricular integration in the processes associated with research through collaborative dynamics centered on the student. Specifically, the results of one of the didactic case studies implemented in two courses during the year 2019 in schools in the Metropolitan Region of Chile are exposed and analyzed. This study addresses introductory phenomena to the study of Newtonian mechanics with springs through collaborative experimentation with the use of smartphones to obtain transversely an approximate value of the acceleration of gravity.

Keywords: Mobile learning, prescriptive curriculum, physics with smartphones, physics teaching.

1 Introduction

In 2018, the Chilean Ministry of Education (MINEDUC in Spanish) finalizes the implementation of the update of its Curricular Bases (CB or BC in Spanish) for education from 7th grade to 2nd grade. In them, a new structure is proposed focused on the achievement of Learning Objectives (LO or OA in Spanish) under a curricular pedagogical purpose. For the case of Natural Sciences, the three main OA expected to be developed are: Thematic Axis OA (TA or ET in Spanish), Attitudinal OA (A) and OA for Scientific Research Skills and Processes (SRSP or HPIC in Spanish). HPIC OAs present particularly new purposes with respect to their predecessor. One of them requires the curricular integration of Information and Communication Technologies (ICT) so that they favor and enhance scientific-school research experiences, emphasizing the processes associated with data collection, treatment, processing and analysis. and information for the development of scientific skills and, consequently, to promote a degree of scientific literacy.

From the requests for curricular updates and their recent implementation, a diversity of pedagogical needs associated with teacher accountability, curriculum coverage, shortage of guidelines, resource scarcity, attention to diversity, etc. emerges. In response to this, it has been decided to design a theoretical-practical model for the mobile curricular integration of the mechanical physics of the second year of secondary education, which will be evaluated by experts and implementation, define the first guidelines on the processes associated with the diversification of the Experimental research practices with smartphone use.

In particular, the results of the application of a case study on the use of mobile technology to obtain the value of gravity acceleration will be described, which is based on the main didactic constructs of the proposed theoretical model. In this way, it is expected to contribute to the pedagogical needs that emerge from the curricular updates of the physics sector in order to establish a current framework of methodological pedagogical processes necessary to design mobile learning strategies that enhance scientific research processes at the same time that the diversification of experimental learning practices be promoted.

2 Background

2.1 Education and curriculum

Education, as a permanent process of construction and social preservation [6], defines a way of living in a community that responds to a model of reality [7]. The curriculum, on the other hand, considers a series of traditions that point to a specific selection of content, skills and attitudes to respond to ethical purposes and for purposes that help the educational improvement from the training process [15].

Both education and curriculum reality have been seen influenced by complex and diverse social processes to over time, being one of the most significant and relevant for this century that of globalization, which represents a series of restructuring processes and how we live today [3]. One of the main social restructuring is materializes in the field of education through the curriculum and its dimensions Deepen the curriculum topic it means then to assume that intellectual changes, both practical and theoretical, they are reflected in all agents of society and in their ethical and moral philosophy. For this last reason, it would be incomplete to assume that, to give response to the wishes, needs and curricular questions, only one type of intellectual opinion will be considered. Is evident that a curricular analysis in what are its three axes most influential: prescriptive, descriptive and hidden [4], requires a thorough reflection of its dimensions emerging and regulated. For this reason, and for the limitations programs in which this study is framed, only delve into the field of curriculum prescription and a case of description.

2.2 Prescribed natural science curriculum

In Chile, the General Education Law (LGE) establishes the rights and duties of community members educational; and sets the minimum requirements that must be demanded at each level of kindergarten, basic and mean [9]. In particular, the LGE establishes through Curriculum Bases (BC) the main objectives of the education for each of the disciplines and their respective axes [11]. This BC statement defines the design curriculum based on the achievement of Learning Objectives (OA) of each of the sectors, including the sector of natural sciences for the axes of physics, chemistry and biology.

The OA for science declared in the BC are of three types: OA of Thematic Axes (ET); OA of Scientific Research Skills and Processes (HPIC); and OA of Attitudes (A). ET OAs define the contents for the teaching of each discipline of natural sciences. The OIC of HPIC, demand rigor before the methodical processes for the development of scholarly scientific research supported using technologies. On the other hand, both ET OAs and HPIC OA consistently develop through ethical-moral attitudes towards science and society through OA A. As a final goal, this type of prescriptive curricular artifact of science establishes as a priority that the student subject, as a critical, participatory and creative individual, understands the need to be educated in science and the processes associated with it [11]. He stresses that the role of teachers should encourage to the enthusiasm, amazement and satisfaction of understanding the nature and technology [10, 11].

Finally, the curricular design described reflects the priorities of influences from international organizations such as the Organization for Economic Cooperation and Development (OECD), which is also based on a curriculum based on the development of skills and therefore on skills, attitudes and knowledge.

2.3 In-depth research process learning

The HPIC OAs, aim to introduce students to the development of the skills involved with the scientific method in a transversal way to the subjects of each level. This last point suggests transdisciplinary support among knowledge.

The HPIC OAs are grouped into five stages, and each of them describes a scientific research process that will allow students to achieve deep learning and also develop critical, creative and reflective thinking, which they can use in all areas of the lifetime. These five stages are: 1. Observe and ask questions, 2. Plan and investigate, 3. Process and analyze evidence, 4. Evaluate, 5. Communicate [11]. The HPIC OAs present in the second-level physics BCs declare, under criteria of scientific rigor, the use and curricular integration of Information and Communication Technologies (ICT) to support and enhance the stages of the scientific research processes on the study of movements, and especially for those stages of the scientific method referred to the collection, treatment, processing and analysis of data and information for the discovery and / or collaborative construction of scientific findings and consensus, and their communication.

Below are the fundamentals and examples of ICT curricular integration through mobile learning mediated by smartphones to develop scientific research processes related to the study of mechanical physics of 2nd grade.

3 Case study design

3.1 Mobile learning in science

The concept of Mobile Learning (ML or AM in Spanish) represents learning that benefits and powers using mobile technology, alone or in combination with any other type of information and communications technology (ICT), in order to facilitate learning at any time and place [16]. Thus, the AM is established from those aspects that are proper to these devices and that have made them look like an artifact that can promote innovation processes in the field of educational technology. Several authors of the last decade [1, 5, 12] have declared the importance of mobile learning to provide solutions to problems in educational contexts. Authors have concluded that mobile technology not only allows benefits to be provided through solutions to educational problems [8], but also "allows the system to be broken to open teaching, involving students in new ways and making educational experiences more meaningful". Being consistent with the constructivist principles, the focus of mobile learning should focus on the learning processes and not on the teaching means, therefore, mobile learning must first and foremost be a type of learning and not a teaching mechanism.

Thanks to the formalizations of international organizations on the AM [16] a floor was developed to know its advantages. The main ones are: 1. The access it provides to pedagogical resources, 2. The connectivity with other people, 3. The connectivity to create content both inside and outside the classroom. UNESCO's conceptualization of AM emphasizes the benefits of mobile technology, to facilitate learning. However, it is necessary to emphasize that mobile learning has little and nothing to do with the physical devices themselves. In the words of some leading authors [8] "mobile learning is the experience and opportunity granted by the evolution of educational technologies. It is any time and place enabled by instant learning, the demand for access to a personalized world full of tools and resources that we prefer for the creation of our own knowledge, to satisfy our curiosities, collaborating with others, and cultivating the experiences that otherwise they would be unattainable "(p. 31). Thus, the AM implies adaptation, a way of being and doing culture in society, represents styles, routines, practices, uses, experiences and opportunities. It also embodies and facilitates the understanding of what it means to be a lifelong learner and what it takes to thrive in today's work [8]. In the specific curricular field of Natural Sciences (NS or CN in Spanish), the AM through curricular integration has shown greater affinity to enhance scientific and research educational practices [2]. Specifically, mobile learning in the teaching of science, and particularly of physics, will be understood from the descriptions of the analyzed authors [8, 16] based on the general conceptualization of scientific literacy, to be characterized as: a type of learning that provides opportunities and experiences to prosper critically and constructively with the natural environment, taking advantage of the potential of mobile technologies.

3.2 Mobile curriculum integration

The definition of curricular integration of technology is nurtured from different lines of work and culminates as a process of articulation through the educational curriculum to respond to the philosophical foundations of society. Outstanding authors [13], have developed the concept of ICT Curricular Integration emphasizing that it allows assessing the educational possibilities of technologies in relation to the objectives of education. Based on this, it is not ICTs that contribute to the educational process but rather the participants of the educational act, methodologies, models and strategies of use, which determine changes, innovation and impact on learning. [13, 14].

Mobile technologies are considered a type of ICT that in educational fields are developed through the AM line. Thus, if the rigorous pedagogical foundations naturally allow mobile technologies to be part of the curriculum, and link them harmoniously with their components, then integration can be established.

3.3 CTS and CTSA approach

The BC define four central elements in the Natural Sciences curriculum, one of them is the relationship between Science, Technology and Society (STS or CTS in Spanish) whose purpose is oriented towards two main objectives. On the one hand, motivate and bring students together in the study of science and, on the other, they understand that scientific and technological applications often cause consequences in the social, economic, political and ethical spheres [11]. With these objectives, students are expected to be able to visualize a practical, concrete and close result of scientific knowledge to understand the impact generated by technoscientific activity in society and everyday life. In this way, the fact that students acquire the skills and abilities that allow them to: Explain their environment scientifically is considered essential for the national context; understand that scientific knowledge is contingent; apply skills to conduct scientific research; develop personal and teamwork attitudes inherent in scientific work; and link scientific knowledge and its applications with the demands of society [11]. The CTS approach also has an extension within the curriculum that considers citizen responsibility fundamental in terms of its relationship between science, technology and society, but within an environmental framework called STSE (CTSA in Spanish).

3.4 General description of the proposal

The development of the didactics is carried out through a sequence of 2 classes that has the support of 3 work guides designed on the basis of specific evaluative indicators of the ET OA No. 10 “Explain, through experimental research , the effects that a net force has on an object, using Newton's laws and the free-body diagram. Particularly, on the application of Hooke's law in various experimental and non-experimental investigations where springs or other elastic materials are used ”and HPIC OAs on“ observation of physical processes and phenomena; identification of problems that can be solved by investigation; experimental research planning with use of instruments, control of variables and explanation of procedures; development of a plan measuring and recording evidence with ICT support; organization of a collaborative work assigning responsibilities and communicating ideas effectively; organization and presentation of data in graphics with the help of ICT; examination and evaluation of the scientific research carried out; communication and explanation of ideas with ICT support ”.

In class 1, two theoretical collaborative activities are developed with support from the first two work guides. In class 2, the second part of the didactic sequence is developed with the help of a third work guide, a ruler and the use of the gyro sensor integrated into the smartphone. In the last class, it is expected that, with the requested instruments and materials, an approximate value of the gravity acceleration module can be determined experimentally through the analysis of the physical variables in the mass-spring system (with the smartphone as mass and simultaneous instrument) (see figure 1).

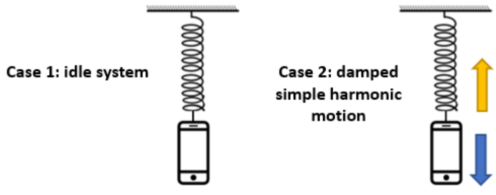


Fig. 1. Graphic assembly for spring-cell analysis.

The first class consists of two parts of approximately 45 minutes each. The first part is about the analysis of four theoretical situations about spring forces for the activation of previous learning related to Newton's principles. To address each situation, collaborative groups of 3 to 4 students are requested to identify the physical variables involved and thereby develop free body diagrams and explain them in their own words. Then, propose at least one hypothesis regarding the hypothetical case of a mass and spring system in oscillatory motion.
The second part of the first class is developed through an analysis and reaction to a reading on bio-inspired robotics that involves the use of springs integrated into the technology (see figure 2). It presents information with which later, in a collaborative way, students must answer 5 development questions, these are: 1. What has caught your attention in reading? 2. What elements or words did you not know? 3. Why do you think robotic designs are inspired by nature? Explain with 2 arguments. 4. In what other ways could springs contribute to society from inspired bio robotics? Find at least 2 new examples and explain them with your words. 5. How do you think physics could contribute to bio-inspired technological designs? 6. What ethical challenges or problems do you think could lead to the misuse of bio-inspired robotics? Explain with at least 2 arguments.

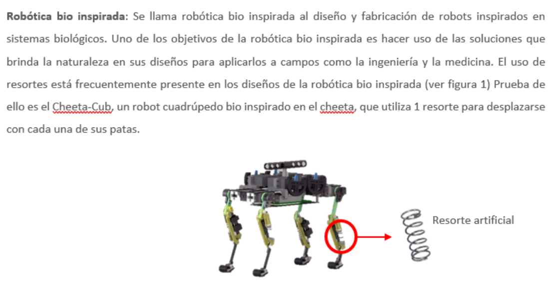

Robótica bio inspirada: Se llama robótica bio inspirada al diseño y fabricación de robots inspirados en sistemas biológicos. Uno de los objetivos de la robótica bio inspirada es hacer uso de las soluciones que brinda la naturaleza en sus diseños para aplicarlos a campos como la ingeniería y la medicina. El uso de resortes está frecuentemente presente en los diseños de la robótica bio inspirada (ver figura 1) Prueba de ello es el Cheeta-Cub, un robot cuadrúpedo bio inspirado en el cheeta, que utiliza 1 resorte para desplazarse con cada una de sus patas.

Fig. 2. Part of the reading for robotics analysis Bio inspired case study.
The second class is composed occupies 90 minutes, distributed in coherence with the structure of a class.

During the experimental activity of the second class, students are asked to perform measurements at specific masses, times and lengths with the help of rules and the mobile application Science Journal. In addition, it is necessary to convert the measurements to the International System (SI) of units of measurement and record these values in the work guides.
Then, using the relevant data and units, the calculations necessary to determine the spring elasticity constant "k" are proposed using two different methods: Note: in both methods, the calculations do not consider rubbing with air.
Method 1: Through a free body diagram analysis, applying Newton's laws.

$$k_1 = \frac{mg}{(L_f - L_i)} \tag{1}$$

To apply the first method, final and initial mass and length measurements are necessary. For this it is necessary to use a balance that allows measuring the mass of the smartphone together with the spring; and a ruler with a length such that it can measure the maximum and minimum elongation of the spring.
Method 2: Through a dampened simple harmonic motion analysis, applying the following expression derived from the circular motion analysis:

$$k_2 = m\left(\frac{2\pi}{\Delta t}\right)^2 = \frac{4m\pi^2}{(\Delta t)^2} \tag{2}$$

In the case of method two, there will be a simple harmonic movement that will be slightly dampened by air as time passes. To perform mass and time measurements, a balance and some mobile application that records the acceleration variations graphically are required. For this case it has been used of the Google ScienceJournal mobile application. To perform the time measurement, the smartphone must be connected to a spring at the back (see figure 1, case 2) and have the application configured to measure acceleration differences on the “y” axis. The procedure consists of dropping the smartphone at a certain height without releasing the spring of which it is attached. In this way, the smartphone will begin to oscillate with the gyroscope sensor on, continuously until it stops by rubbing with the air. To maintain good control of the variables, any possible friction, involuntary movements in other axes, and hand impulses should be avoided.
After at least 5 seconds have elapsed, the smartphone will record the variations in the acceleration of the gyroscope and graph them together with a time record, which can be used (see figure 4).

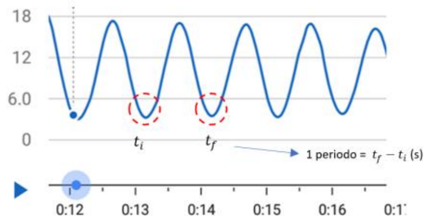


Fig. 4. Measurements of the oscillation period of the damped simple harmonic movement, spring-smartphone system.

It should be mentioned that because the movement is generated in a material medium such as air, it will become dampened, and, therefore, will lose energy after a few seconds (see figure 5), for this reason it is considered relevant that Measurements to the oscillation period are made in registration sections as homogeneous as possible.

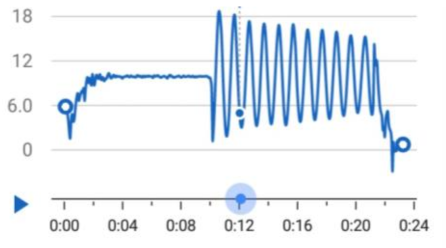


Fig. 5. Analysis of the buffered measurements in the spring-smartphone system.

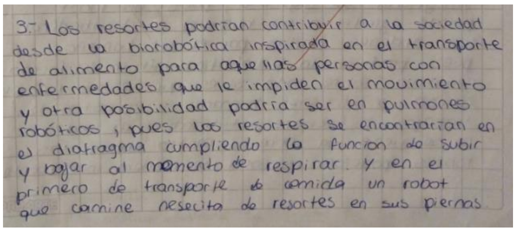
After the experimental determination of both elasticity constants, the second one is used to determine the approximate value of the acceleration of gravity by replacing it in equation (1) and using the measured length and mass values.
In addition, the discussion on the results found is promoted, opening the debate on the consequences of rubbing with the air and the variations in the values of the acceleration of gravity.

3.5 Learning assessment

In order to measure the development of scientific competences, the evaluation was chosen based on the use of rubrics, checklists and group self-assessments. These instruments have been chosen because they allow characterization with qualitative and quantitative indicators of student performance, and thanks to their versatility they can easily adapt to the methodological strategies that teachers deem most convenient.
The rubrics have been designed with the objective of measuring the levels of achievement of the developments of each activity presented in the collaborative work guide. It has been chosen to use a spectrum of 3 levels of achievement: Totally maximum, average achieved, minimum achievement. This, to characterize the most significant advances of each stage of the didactic sequence. The rubric allows various measurements to be made consistent with the five stages of the research process required in a curricular manner, to demonstrate behaviors that obey the observation of phenomena, the questioning and hypothesis, the planning and conducting of the research activity, the processing and analysis of data (see figures 3, 4 and 5), evaluation and communication of conclusions. The checklist has been designed to measure experimental manipulation and collaborative work observed during class. The self-assessment that students do is not weighted with a grade. Its purpose is to provide feedback to the teacher about the collaborative work performed by the groups, also promoting criticism and self-criticism.

4 Results and discussions

In general, the measurements of the rubrics based on evaluation indicators according to the curricular OA, account for 80% of students with favorable results, with more than 75% well answered on the total. On the results of the first part of the first class, diagrams and analysis of problematic situations, it On the results of the first part of the first class, the diagrams and the analyzes to problematic situations, it was possible to develop most of the problems posed without difficulties, managing to apply the Newtonian principles seen in previous classes, drawing and identifying the forces with Diagram support, and textual application. Difficulties, managing to apply the principles of Newton seen in previous classes, draw and identify the forces with Diagram support, and textual application. Regarding the results to the CTSA of the second part, critical reflections were evidenced on the applicability of the springs (see figure 6), and the physical principles studied from bio-inspired technologies, emphasizing the link with nature; proposals for the contribution of applied science to technology; and the challenges and problems of abuse and misuse of such technologies.



3- Los resortes podrian contribuir a la sociedad desde la biorobótica inspirada en el transporte de alimento para aquellas personas con enfermedades que le impiden el movimiento y otra posibilidad podria ser en pulmones robóticos, pues los resortes se encontrarian en el diafragma cumpliendo la funcion de subir y bajar al momento de respirar. Y en el primero de transporte de comida un robot que camine nesecita de resortes en sus piernas

Fig. 6. Answers of a group of students.

Regarding mobile learning, the results of the second work guide show elements of the development of collaborative research carried out by students, emphasizing some difficulties with the approach to research hypotheses. However, the collection and processing of data enhanced using smartphone sensors, their analysis and interpretation, the rigor in the calculations, and the reflection and conclusion processes are satisfactory in terms of high compliance achievement. It is also noted that, within the development of the second work guide with one of the courses with 4 collaborative groups, approximate values of the gravity acceleration module have been obtained with a percentage error with respect to the theoretical value that ranges between 4.38% and 9.07%, as shown in table 1.

Collaborative groups	$g_{teo}\left(\frac{m}{s^2}\right)$	$g_{exp}\left(\frac{m}{s^2}\right)$	$\varepsilon\%$
1	9.81	9.08	7.44
2		8.92	9.07
3		10.44	6.42
4		9.38	4.38

Table. 1. Variation of the values of the experimental determination of the acceleration of gravity with smartphone.

5 Final consideration and future work

The didactic experience of mobile curricular integration with grafts of CTSA approach has been favorable in terms of the above. The specific indicators of the proposed HPIC OA have been achieved. However, the percentage errors in the calculation of the acceleration of gravity during the guided research process carried out by the students are still high and can unnecessarily lead to conceptual errors. For this reason it is prudent, for future work, to establish strategies that, for this type of experience, allow us to understand and justify the errors associated with the variables that interfered with the phenomenon, and on the other, to take actions that allow them to be reduced and deepen your explanation. The comments on collaborative work have been positive. It is noted that the attitude of the students during the application of the case study was favorable throughout the activity, showing great interest in knowing the operation of mobile devices, and using them to generate experiences that would allow them to learn.

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