and this fact can make the mole method more difficult. Therefore we used 96 g, because it also can easily be divided into two parts, and the amount of substance can easily be calculated from this mass.

As we noted earlier, in Hungary the mole method is the suggested strategy contrary to the Germany, where the proportionality method is advised (SCHMIDT, 1994). It is noticeable that the proportionality method (strategy 2) is closer to the logical method (strategy 3) than the mole method (strategy 1).

The grade 11, 12 and 13 German high school students having 3 or 5 lessons of chemistry per week probably are much more familiar with solving chemistry problems than our grade 7, 8, 9, 10 and 11 students learning chemistry in 2 lessons per week. Probable experts can develop their logical methods easier than novices, who usually are looking for algorithms to solve a problem. If this is so, we can suggest an implication for classroom practice: it would be worth trying the method suggested by SCHMIDT (1997) for introducing stoichiometric problem solving and improving students' problem-solving thinking.

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Football: effect of increasing goal size on the number of goals
Fútbol: efecto del incremento de tamaño de las porterías en el número de goles

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Abstract

Here is an example of elastic collision to be presented in a contextual manner to a physics class. Namely, the effect of increasing goal mouth size on the number of goals scored in a football match is discussed, considering elastic collisions of the ball with the posts. The results are compared with data taken from the Spanish Professional League, that show a high number of shots-to-post. Surprisingly, there is a direct correlation of the increase in goal mouth area with the increase of goals.

Key words: *physics, elastic collision, soccer, goal size.*

Resumen

Se presenta un ejemplo de colisión elástica para ser mostrado de un modo informal en una clase de física. En particular se discute el efecto que tendría un incremento del tamaño de las porterías en el número de goles de los partidos de fútbol, tras considerar que las colisiones del balón con los postes son elásticas. Los resultados se comparan con datos obtenidos de la Liga de Fútbol Profesional de España, que muestran un número muy alto de balones al poste. Sorprendentemente, hay una correlación directa entre el incremento de área de la portería y el incremento de goles.

Palabras clave: *física, colisión elástica, fútbol, tamaño de portería.*

The popularity of some sports is a good resource to attract students' interest. In this way, the creation of scientific attitudes in the analysis of any aspect of daily life, or the introduction of specific concepts of any particular subject, are more effective if they are incorporated in non-conventional or even surprising examples. Here is presented one such example, involving football, in which the concept of elastic collision as well as the quantification of curious facts, are made.

Football is the most popular sport in Europe, and a major area of economic activity: in Spain, for example, figures from the Professional Football League suggest that the football industry accounts for 1% of Gross National Product. In the rest of the world, football's influence is increasing apace. Given such significant repercussions, it is interesting to consider whether it might be possible to improve the game's entertainment value on the basis of analyses of play situations (OUDEJANS et al., 2000), or even by introducing changes in the rules. Clearly, goals are the crowning moments of a match. Typically however, the number of goals scored is small, and not surprisingly many matches end as 0-0 draws. One proposal for increasing the number of goals has been to increase the size of the goal mouth. In an attempt to quantify the likely consequences of such a measure, summary statistics for First Division matches in the Spanish Professional League, 2000-2001 season (Guía Marca, 2002), have been analysed. The total number of shots-at-goal hitting the post (and not going in) was 231. Given that the total number of goals in this period was 1095, in 380 matches (2.88 goals per match), expressing shots-to-post as a percentage of goals scored gives 21.1%, a higher proportion than expected given the small frontal area of the posts (which are at most 12 cm thick). The effect of varying goal size on number of goals can be estimated as follows (under the simplifying assumptions that all shots are perpendicular to the goal line and that the ball's collisions with the cylindrical posts are perfectly elastic): if the goal mouth were expanded laterally and vertically by one ball-diameter (rules require ball diameter to be between 21.6 and 22.3 cm) plus 7 cm, then all current shots-to-post would be goals (whether without hitting the new posts or after hitting them). The 7-cm increase is necessary to ensure that the ball changes direction by at least 90 degrees after the collision, even in the least favourable case. Of course, further refinements of the model might be considered (relating to shot angles, shot probabilities across the goal area, and new play situations created after rebounds from the posts of the enlarged goal mouth); however, the simple model is probably sufficient. Increasing goal size in such way means an increase from 2.44 m x 7.32 m (17.86 m^2) to 2.73 m x 7.90 m (21.57 m^2). This percentage increase in area, 20.8%, is almost equal to the above-noted increase in goals (21.1%), which is rather surprising. Taking into account that the increase in goals would occur at the edges of the goal, less accessible to the goalkeeper, in principle the probability of goal in the "new" area should be higher than in the central areas where the keeper spends more of his time.

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