Interdisciplinary study of fluid dynamics using interactive conceptual maps

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Abstract

Nowaday students don't want to study in the way their parents did. The problem could be solved by changing the teaching methods, by creating a constructivist learning environment. This paper proposes an interdisciplinary study of the fluids in our lives through conceptual maps, by combining the fields of instruction and technology. The concept map, made on three levels, introduces a presentation in Microsoft Office Power Point 365 with some hyperlinks to 3D educational animations on the Mozabook digital interactive lesson creation platform through which the teacher can show his creativity in teaching. Level 2 concept map is an exposition of fluids in science. The level 3 concept map presents some applications of fluid dynamics in biophysics, more specifically in blood circulation, namely: the first application involved calculating the speed of blood flow through the aorta, the second application estimated the value of Reynolds number for blood flow through the aorta, through the third application the value of the blood speed in the capillaries was obtained and the last one refers to the pressure exerted by the blood on the walls of the blood vessels, being able to explain the phenomenon of regulating blood flow through fluid dynamics laws.

Keywords: fluid's dynamics, conceptual maps, interdisciplinarity.

1.Introduction

Most published articles describing the use of the concept map concept refer to Novak and Gowin. The “Novakian standard concept map format” is used on the IHMC CmapTools website (Cañas and al, 2004) as well as on the website of the First International Conference on Mapping Concepts (Åhlberg, 2004). The development of efficient pedagogical strategies has led to an understanding of how students learn, so that they can easily deepen and retain new concepts. When concept maps are integrated in a way significant and systematic in teaching, the effectiveness is better compared to the usual modes of teaching (Osman and al, 2013).

2.Concept mapping: a short theoretical background

From the perspective of the cognitive theory of learning on the behavioural approach of the 1960s, the teaching had to be carried out so that the learning material was conceptually clear and adapted to the previous knowledge of the students (Ausubel, 1968). As educational research tools, concept maps were used as data analysis tools in 1972 (Novak and Cañas, 2006). The importance of students' prior knowledge inspired Novak and Gowin to introduce teaching alternatives, including concept maps. They also observed that making concept maps is a creative activity, in which the student makes sustained efforts to clarify the meanings of concepts in a particular field (Novak and Gowin, 1984). Since 2000, Edmondson says concept maps have been widely used for effective teaching. The map was useful not only in presenting the qualitative aspects of learning, but could also be used as an assessment tool (Edmondson, 2000). In the teaching and learning processes, the conceptual map is used to introduce new information based on the knowledge that students already possess (Gurlitt, and Renkl, 2010). It was later shown that the concept map is useful for knowledge transfer in several stages of learning, namely: acquisition, communication, application, acceptance and assimilation (Tseng and al, 2012).

3.Interdisciplinarity in fluid dynamic's

Liquids dominate physical phenomena from the microscopic scale of biological activities to the macroscopic scale of galactic structures. Fluids more or less ensure our comfort, indoors or outdoors, influence our recreational and entertainment activities (McDonough, 2009). As it is quite difficult to maintain the concentration of high school students during one class, it is important to use the computer during teaching activities. Technology causes major changes if used in the classroom (Bransford et al, 1999). Solving students' concentration problems involves a different way of interdisciplinary teaching of physics, using graphic organizers.

4.The constructivist approach of the fluid's dynamics

A constructivist environment is inclusive, interactive and receptive that generates cooperative learning and reflects a democratic management and organization that allows teachers and students to share responsibility in decision making (Aitken and Deaker, 2008).

In the conceptual map presented in figure 1, the main concept is "fluid dynamics", fluids that at pre-university level can be studied both within the "ideal fluid" model as well as "real fluids", a situation encountered in reality. Starting from the "ideal fluid model", the properties of the ideal fluids were described, namely the fact that they are incompressible and free of viscosity. The level 1 concept map shows the quantities that characterize the ideal fluid flow: mass flow, volume flow and the relationship between them. These are given by relations [1], [2] and [3].

[1] $$Q_m = \frac{dm}{dt}$$

[2] $$Q_v = \frac{dV}{dt} = \frac{Svdt}{dt} = Sv = S\pi r^2$$

[3] $$\frac{dm}{dt} = \frac{d}{dt}\int_{R(t)} \rho dV = 0$$

The incompressibility of fluids and the fact that they are continuous structures implies a finding that boils down to the continuity equation presented and its differential form, a form that could be taught in the eleventh grade, because students had the necessary mathematical analysis understanding. Bernoulli's equation [4] shows students that along a current tube the total pressure in the fluid is constant.

[4] $$p_1 + \frac{\rho U_1^2}{2} + \rho g h_1 = p_2 + \frac{\rho U_2^2}{2} + \rho g h_2$$

[5] $$\nabla \times U = 0$$

Equation (5) tells us that velocities are an irrational field. The two equations [3] and [4] are valid for the ideal fluid model, as shown in Figure 1.

The continuity equation [3], which appears in the first level of conceptual map, is also valid in the case of blood circulation through blood vessels, circulation shown in figure 3.

The flow of a fluid through a hole gives rise to reaction forces on the rest of the system. The force, determined by the impulse variation, is friction, independent of the fluid density. This reaction force, given by relation [6] is an application of fluid dynamics and is also presented in the level 1 concept map. This effect is used for rocket propulsion studied as the movement of a solid in a fluid, in connection with the aerodynamic lift.

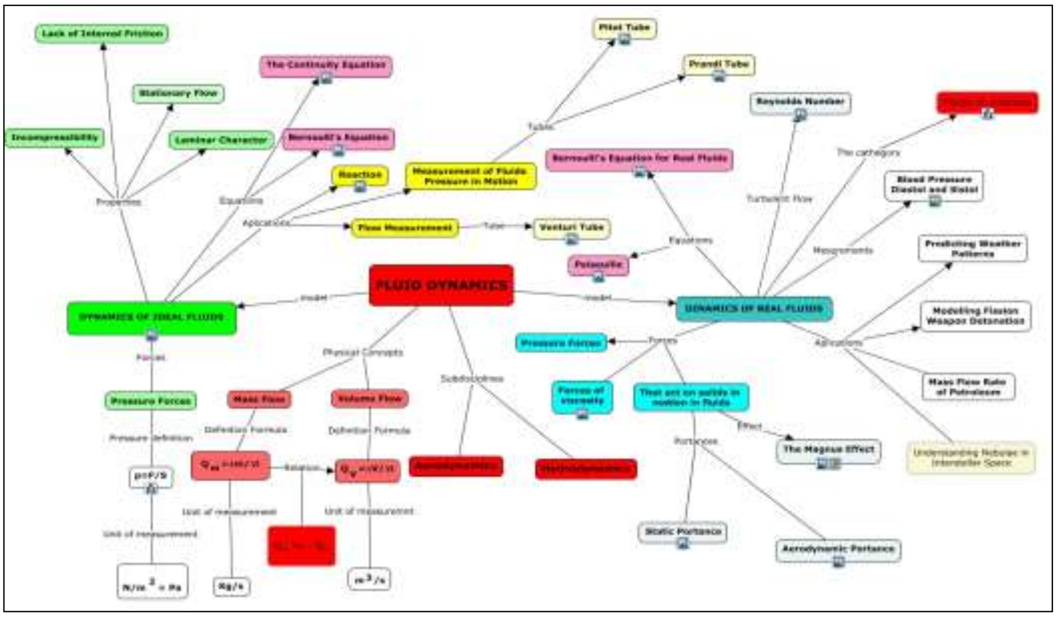


Figure 1. The first level of conceptual map; ideal and real fluids

[6] $f_{reaction} = \dfrac{v\Delta m}{\Delta t} = \rho S v^2 = 2S\left(p - p_a\right)$

Starting from Bernoulli's equation [4] we were able to explain to students its practical applications in aeronautics: Pitot Tube and Prandtl Tube. Also in the first level of conceptual map appear the Pitot type probe, which allows the measurement of the total pressure and the Prandtl type probe needed to measure the dynamic pressure, which uses the manometer in a differential assembly. In the processes where permanent pressure loss is not tolerable are used Venturi Tubes. Also Venturi Tubes are used where maximum accuracy is needed in case of highly viscous liquids.

Referring to the dynamics of real fluids, the classification of the type of laminar, turbulent or transition flow between the two types is made according to the Reynolds number given by equation [7]:

[7] $R_e = \dfrac{\rho D \bar{v}}{\eta}$

The resistance force in the case of a body moving in a fluid depends on the square of the speed of movement of the body but also on its surface, as observed in relation (8).

[8] $F_r = C \cdot S \cdot \dfrac{1}{2} \rho v^2$

Relation (9) is obtained from the elementary volume flow of liquid flowing through a portion between r and și $r + dr$.

[9] $dQ_V = v(r) dS = \dfrac{\left(R^2 - r^2\right)}{4 l \eta} 2\pi r dr$ z, where $dS = 2\pi r dr$ it represents the area of the circular crown.

$$[10]\quad Q_V = \frac{\pi R^4}{8\eta} \cdot \frac{p}{L}$$

According to Poiseuille's formula, given by relation [10], a doubling of the pipe diameter caused a 16-fold increase in flow, while keeping the diameter constant, the same effect could be obtained by a 16-fold increase in pressure. The effect is used in medical practice, when it is necessary to introduce fluids into the body under conditions of physiologically limited pressure and the flow is important for the success of the maneuver.

As fluids are found everywhere, from the microscopic to the macroscopic level, students were asked to find applications of fluid dynamics, applications found in the level 2 concept map in Figure 2, which shows the dynamics of fluids found in science: atmospheric physics, oceanography, geophysics. The volcanic eruptions that cause earthquakes and the movement of tectonic plates are part of the category of convection phenomena in the Earth's mantle. In the Earth's core, the convection phenomenon determines the appearance of its own magnetic field. Following the concepts in the macroscopic domain of the second level of conceptual map, we arrive at astrophysics, the movement of galactic structures and stellar evolutions from gravitational collapse to death as supernovae.

Fluid dynamics is found in cellular processes and in the respiratory and circulatory systems of organisms. Because the heart is the central organ of the blood circulation system, the study of the heart has been very suitable for an interdisciplinary study. Having the role of pumping blood in the network of vessels made up of the arterial and

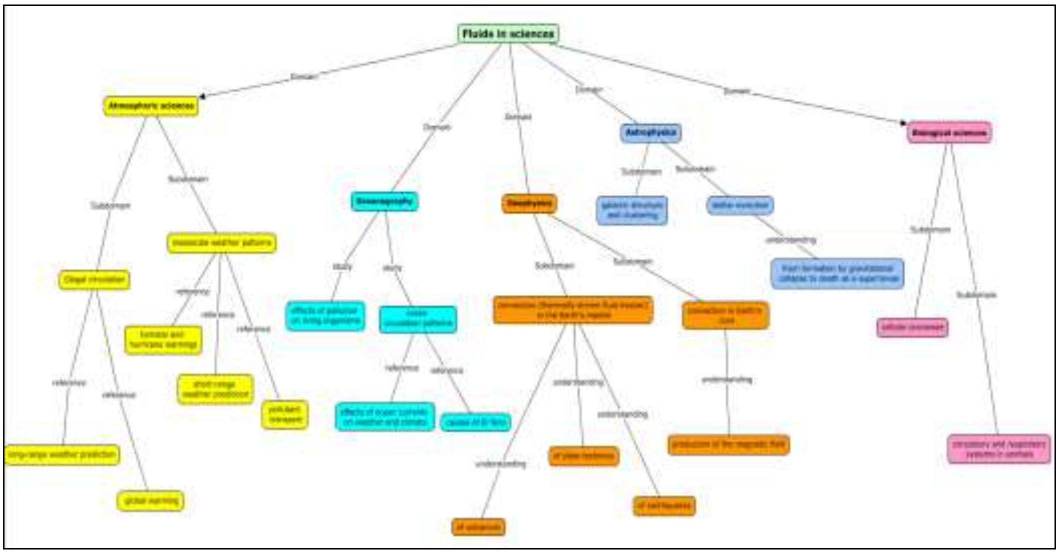


Figure 2. The second level of conceptual map; fluids in science

venous shaft, the heart could be likened to a double suction-repellent pump, with ”coupled” circuits: one circuit is of the lungs, the other of the rest of the body.

In Microsoft Office Power Point 365 you can insert a hyperlink to a 3D model of the heart, which can be rotated and viewed from all angles. The 3D models were taken from the Mozabook interactive digital lesson creation platform. The insertion of the 3D model is shown in Figure 3. To view the 3D animation on the computer you must install the m3dviewer program that can be used on both Windows 10 and Android.

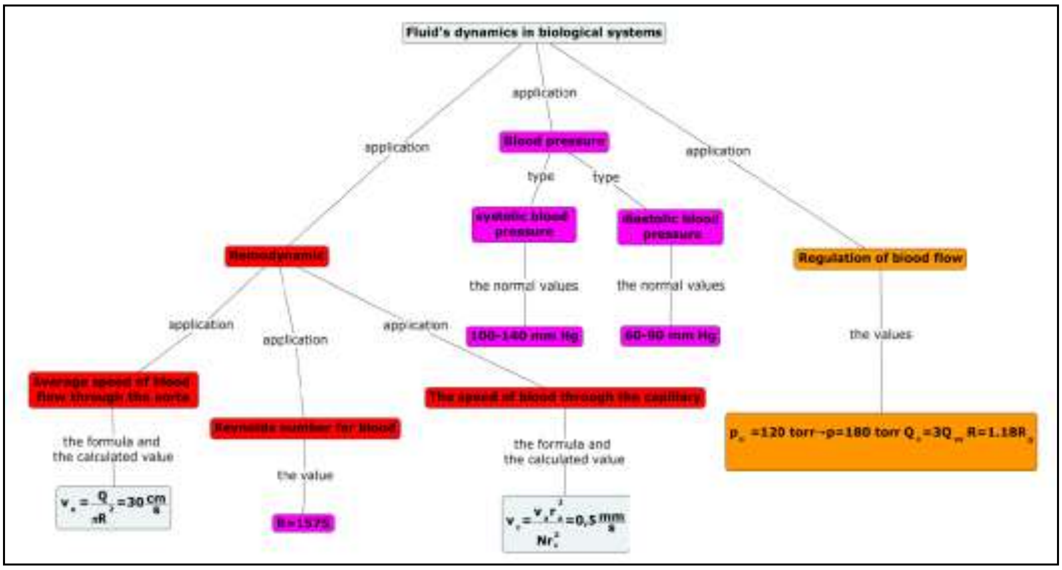
Figure 3. The insert of 3D animation in Microsoft Office Power Point 365 from Mozabook

The third level of conceptual map in Figure 4 shows three applications of fluid dynamics in biophysics and, more specifically, in blood circulation.

The first application involved calculating the speed of blood flow. Knowing that the volume of blood flows through the aorta $Q_v = 5{,}65\frac{l}{\min}$ and the value of the radius of the aorta $r = 1\text{cm}$, we were able to calculate the average speed of blood flow through the aorta. Starting from the relation [2] that connects the volume flow to the flow rate, it results:

Figure 4. The third level of conceptual map; fluid's dynamic in biological systems

[11] $v = \frac{Q}{\pi r^2} = 30\frac{cm}{s}$



By a second application it was possible to estimate the value of the Reynolds number for the flow of blood through the aorta, considering the density of the blood $\rho = 1050\frac{Kg}{m^3}$, $r = 1$ cm, blood velocity $v = 30\frac{cm}{s}$ and the viscosity coefficient $\eta = 4.10^{-3} daP$. Using formula [7] we obtain R=1575, so the students came to the following conclusion: the blood flow through the aorta is laminar and is quite close to a turbulent one.

The third application referred to the calculation of blood velocity in capillaries. The blood in the aorta finally reaches the capillary network. The radius of the aorta is given above, the number of capillaries in the human body is approximately $N = 4\cdot 10^9$ and their average radius is $r_c = 4\cdot 10^{-4} cm$. Starting from these values it was possible to determine the speed of the blood through capillaries. We considered blood as an incompressible fluid, we applied the continuity equation [3] in the form:

[12] $v_a S_a = N v_c S_c$

where v_a is the speed of the blood through the aorta, S_a the area of the aortic section, v_c is the speed of the blood through the capillaries and S_c the area of the capillary section. Then:

[13] $v_a \pi r_a^2 = N v_c \pi r_c^2$ and it results:

[14] $v_c = \frac{v_a r_a^2}{N r_c^2} = 0{,}5\cdot 10^{-3}\frac{m}{s}$

Another application in the level 3 concept map is the pressure exerted by the blood on the walls of the blood vessels. Because the contraction and relaxation of the heart causes an oscillating flow of blood through the human body, blood pressure must be measured both at the time of heart contraction-systole and at the time of relaxation-diastole.

And the regulation of blood flow could be explained using fluid dynamics. Blood pressure when the body is at rest is p_0=120 torr and the blood flow is $Q_{v0}=5\frac{l}{\min}$. In the case of physical effort it increases to $Q_v=15\frac{l}{\min}$ and the pressure at p=180 torr. Then from the relation of Poiseuille (9) it was obtained:

[15] $Q_0 = \frac{\pi R_o^4}{8\eta L} p_0$

[16] $Q = 3Q_0 = \frac{\pi R^4}{8\eta L} p$

It follows from relations [15] and [16] that $R = 1.18 R_0$. This means that the radius of the artery increases. So, by changing the radius of the blood vessels in the arterial system, the blood flow is controlled and the increase in blood flow is done without the pressure in the blood vessels increasing much. It follows that the arteriole system largely controls blood flow.

Conclusions:

Interactive tools can be used in the teaching, learning and assessment processes. The concepts and connecting words were chosen carefully, so that the concept maps have become particularly useful tools for observing the nuances, helping the students in organizing the thinking, summarizing the studied subject. From an educational perspective, a growing number of researchers in the field indicate that the use of concept maps can significantly facilitate learning (Coffey and al, 2003). The result was a spatial organization of knowledge about fluids and their dynamics. The students built their own maps using a version of CmapTools, and the goal was for the students to succeed in their study efforts. Concept maps have contributed to improving the quality of teaching and evaluation of fluid dynamics in pre-university education, being designed as computer tools in a constructivist environment.

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