Active Learning on Paradoxical Phenomena in the Fluid Pressure

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Abstract. Several cases studies for the development of a simple experimental method for fluid pressure are reported. It is included how to carry out a home-made experiment for active and deep learning using paradoxical phenomena on those. In this study we proposed a simple experimental equipment at home using inexpensive 100-yen store items recent information and communication technology(ICT) tools for clear pressure visualization. We present practical examples of modern reconstructions for historically valuable teaching methods in the Meiji Era, those resolve such as E.H. Graf's "Buoyancy Paradox" around fluid pressure by finding suitable experimental methods with bargains goods.

1 Historical investigation from the Archimedes principle to the Pascal's Law

We are developing ICT-based active learning (AL) modules[1] in science education using hands-on tools for modern reconstructions of historically valuable teaching materials of the Meiji Era via comprehensive studies for students' notes on Newtonian Mechanics, etc.

In this paper, we focus on fluid pressure in static fluid mechanics. Using our hands-on suction valves, we first conduct some historical investigations on the Archimedes' principle and the Pascal's Law in static fluid mechanics for a clear understanding of the E.H. Graf's "Buoyancy Paradox" [2]. In "On Floating Bodies," given by Archimedes, he suggested that (c. 246 BC): Any object, totally or partially immersed in a fluid, becomes lighter (buoyed up) due to a force equal to the weight of the fluid displaced by the object. Further, in ref.2, E.H. Graf stated that: "A solid heavier than a fluid will, if placed in it, descend to the bottom of the fluid, and the solid will, when weighed in the fluid, be lighter than its true weight by the weight of the fluid displaced." However, the fluids described by Archimedes are not self-gravitating since he assumes the existence of a center point M, toward which all things fall (Fig. 1-A). Therefore the meaning of the bottom of the water fluid not well defined as Fig.1-A in Archimedes' Era.

Blaise Pascal established not only the concept of "fluid pressure" but also the method of creating a vacuum at the top of the mercury column to measure pressure. It is especially noted that in contrast to Graf's statements in "Proposition 7", verifications on Fluid Pressure in the case of Pascal's demo as shown in Fig. 1-B, under of the W (Wood in Piston cylinder) has no buoyancy due to no water, at the bottom in Fig. 1-B&C (our transformed version of B), because of no fluid water beneath W. Then Graf's statements create serious contradictions named "Graf's Buoyancy Paradox" with no upward pressures in Fig. 1- B&C. In the next section, we try to make a fundamental clarification to resolve "Graf's buoyancy Paradox" weighed in fluid, but no water beneath W.

This "Buoyancy Paradox" has been hot topics of science education mailing list in the past several years and has attracted a great deal of attention, particularly as an error in questions of entrance examinations for high schools. However, those serious contradictions are far

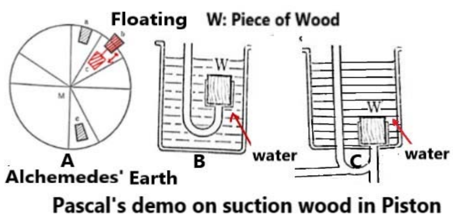

Fig. 1 Archimedes' Earth and Pascal's demos on suction wood in piston as B and C.

from being completely solved yet, and fundamental clarification of those is strongly expected.

2 E. H. Graf's "Buoyancy Paradox" and clear experimental solutions for his contradictions

In this section, we try to clarify E. H. Graf's "Buoyancy Paradox". He wondered what if the object is resting on the bottom and there is no fluid beneath it. He determined "the apparent static weight" by following step-by-step ways as Fig. 2-X [2]. 1) Place the submerged object on the scale and record the reading. 2) Remove the object and record the scale reading. 3) The difference in readings is the apparent weight. [2]

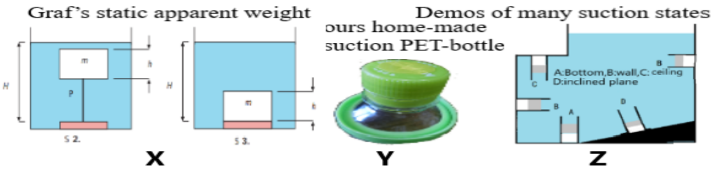

Fig.2 Graf's apparent weight and Ours Demos using suction-caps in A,B,C,D states

Furthermore, "Graf justifies his procedure" because it is similar to that which we would use to determine an object's true weight in the air. It always becomes lighter than its actual weight by the weight of the fluid displaced even if there is no buoyancy fluid beneath it, i.e., it is a serious contradiction! However, the critical history for understanding buoyancy by Pascal's Law on the object in fluid is well investigated in "Mach Mechanics [3]". In our talk, we demonstrate AL methods for fluid pressure focusing on the deeper conceptual understandings on key points of " buoyancy paradox" using the hands-on experimental tools shown Fig.2-Y and we investigations on fluid mechanics from Archimedes to Galilei, Pascal, Mach's books. Now we show some typical examples of modern reconstructions for historically valuable teaching methods in the Meiji Era to resolve thee paradoxical phenomena around fluid pressures. We report on some new practices for developing the visualized ICT-based AL through demonstrations via such suction valves; namely, a home-made suction cap made from the top cut part of a PET-bottle (Fig.2-Y), where the bottom is covered with silicone for sealing, and the top-cover has a valve structure for pressure reduction. The demonstrations of resolving the various paradox on fluid pressures are achieved by finding the new experimental methods to visuarize both pressure values inner and outer sides of suction caps for Fig.2-Z; A~D states. We show that it's impossible to justify the "Graf's procedures" in the case of B, C, D states.

3 Conclusion

If the fluid is divided by the boundary of the silicon sealing of the suction cap (Fig. 2-Y), the reference value of fluid pressure will be different in each divided area. Therefore, the pressure values inside and outside any suction caps in states A, B, C, and D (Figure 2-Z) will be different. We present the development of experimental methods using such a visualization sensor, and the importance of deep learning of paradoxical phenomena using ICT-based AL.

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